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SYSTEM CONTROL FOR THE TRANSITIONAL DCS.(U)

JUL 79 F C ANNAND, D E DOTY, R V KRZYZANOWSKI DCA100-78-C-0017

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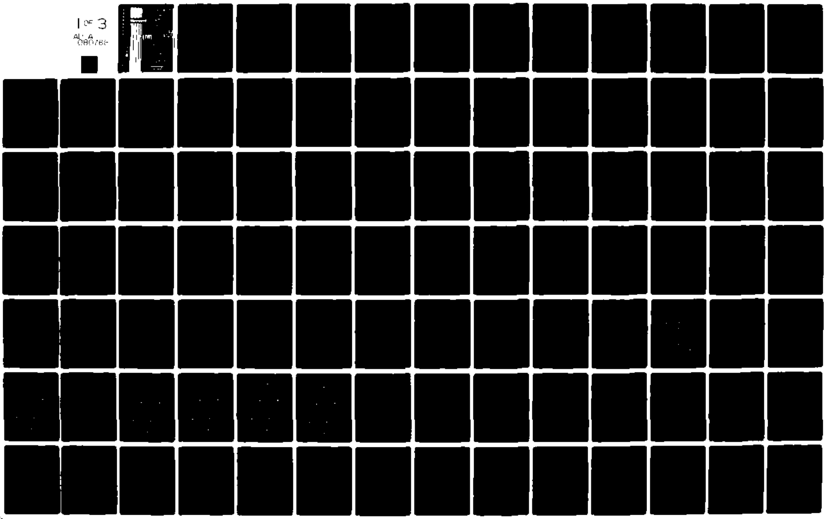

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This report, the fourth in a series of technical reports, summarizes t[...] effort which was undertaken in two tasks. The report focuses on the a[...]pated DCS of the mid 1980's. It discusses information sources, inform[...] collection, data base organization and displays and provides recommend[...] The report also addresses control actions and algorithms for their imp[...]tion. The algorithms include data base searches for providing altrout[...] recovering to normal routes and techniques for controlling routing in

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overseas AUTOVON system. Assessments of the software and hardware requirements, associated costs and benefits are included.

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SECTION 1

INTRODUCTION AND SUMMARY

1.0 PURPOSE AND ORGANIZATION OF THE REPORT

This report describes the results of the System Control for the Transitional Defense Communications System (DCS) study. This study defines the functional characteristics of an automated system which will provide the information collection and utilization capabilities needed by the theatre level in the performance of its real-time mission and the relationship of this system to lower-level control systems. This is the fourth technical report for this study containing a summary of the entire effort, the results of hardware/software size and cost estimating activities, and an analysis of the impact of the recommended system on manpower requirements.

Report 1 in this study (Reference 1) establishes the assumed characteristics of the DCS in the mid 1980's. Report 2 (Reference 2) discusses the information collection, data base organization, and display recommendations for system control. Report 3 (Reference 3) discusses control actions which can be taken and algorithms for their implementation. The majority of Report 3 is a presentation of an algorithm for performing automatic searches for altroutes in the data base developed in Report 2. Other algorithms presented involve controlling the routing in the AUTOVON system.

The remainder of this section describes the baseline assumptions made about operational philosophy and subsystem deployment. A top-level overview of the recommended system, along with its costs and benefits, is presented. This section concludes with recommendations of future studies in the system control area.

Section 2 provides a summary of the recommendations relating to control of transmission resources including collection of parameters, data base and display design, and automatic altroute searching algorithms.

Section 3 is the summary of controls for the European automatic voice operated network (AUTOVON) circuit switched network.

Section 4 contains the results of the final design tasks of the study. It describes the implementation of controls and provides cost and size estimates for the entire recommended system control subsystem, including both parameter collection and control activation portions.

There are three appendices in this report. Appendix A presents some representative examples of altroute search algorithm execution. These examples were created in order to estimate the time required to perform such a search. The most complicated example, generating a restoral plan for a complete failure of the Swingate-Houtem link, required about nine seconds of execution time.

Appendix B contains the analysis of the impact of the altroute searching algorithms and the use of remotely controlled patching devices called channel reconfiguration units (CRU) on manpower requirements for DCS operations.

Appendix C contains the detailed size estimated for the altroute search algorithm software.

1.1 PHILOSOPHY OF SYSTEM CONTROL

The underlying philosophy in designing the control system in this study is that control will take place at the lowest level in the hierarchy which can feasibly perform it. When problems occur which cannot be solved at any level due to coordination requirements or for wider system visibility, the control responsibility will be moved to the next higher level. In this manner, problems "bubble up" from the lowest level to whatever level has the visibility to solve them. This philosophy minimizes the involvement of higher system control levels in the routine operation of system resources and provides a more uniform distribution of control system loading across the levels of the control hierarchy. As a result, the response is quicker, the system survivability is enhanced, and good utilization of equipment and personnel is achieved.

The capability for real-time control is already being developed for the transmission system at levels below theatre. The automated technical control (ATEC) system will provide these capabilities for the terrestrial transmission system, and defense satellite communication system/control segment (DSCS/CS) will provide them for the satellite system. Switched networks basically have a two-level hierarchy, consisting of the switches themselves at the lower level and the theatre control at the higher level. Therefore the focus of this study is those functions which occur at the theatre level and modifications at the lower levels to support those functions.

Because of this philosophy of control, the control system design addresses the following areas:

- Establishment of a real-time function for world wide on-line system/area communications operations center (WWOLS/ACOC)
- Reporting of subsystem parameters to the WWOLS/ACOC
- Analysis of parameter consolidation which occurs during upward reporting
- Definition of controls requiring area-wide visibility
- Additional hardware or software which will make control more effective

1.2 THE DEPLOYMENT MODEL

1.2.1 Purpose of a Deployment Model

A model provides a typical subsystem configuration of DCS equipment. The model can then serve to define the inter-subsystem interfaces of an area-wide control system and specify the parameter reporting and controls of the WWOLS/ACOC control level.

1.2.2 Transmission System Deployment Model

The model used is a simplified representation of the European DCS backbone. This representation is used as opposed to some hypothetical model because it provides all of the DCS characteristics of the mid-1980's and is

at least as complex as any DCS area. In addition, using a realistic model brings some of the DCS peculiarities into the model which might be overlooked in a hypothetical model development.

The transmission system deployment model and the ATEC hierarchy assignments used in this study are presented in Figure 1-1. The backbone connectivity and equipment is the state of the European network after the DEB IV digitization plan is implemented.

The details of each link are given in Figure 1-2. The connected stations, link number, and type of transmission radio are listed for every link. The transmission links are primarily microwave line of sight (LOS) radio and digital multiplex equipment as specified by the DRAMA specifications. Digital tropo scatter radios are also present. Satellite terminals are identified as well as the links they support. The DSCS III satellite is assumed for all satellite links. The mileage of the links are stated along each link, and the layout of the network gives a rough geographical view of the deployment. Finally, the links of the European theater to the Continental United States (CONUS) are identified in order to show inter-area linking requirements.

1.2.3 Common User Network Deployment

The common user switched networks modeled for this study were assumed to have the following characteristics:

- Data and narrative/message traffic are carried over an automatic data interchange network (AUTODIN II) system consisting of three packet switching nodes, identical to those being developed for CONUS, replacing the current AUTODIN I switches.

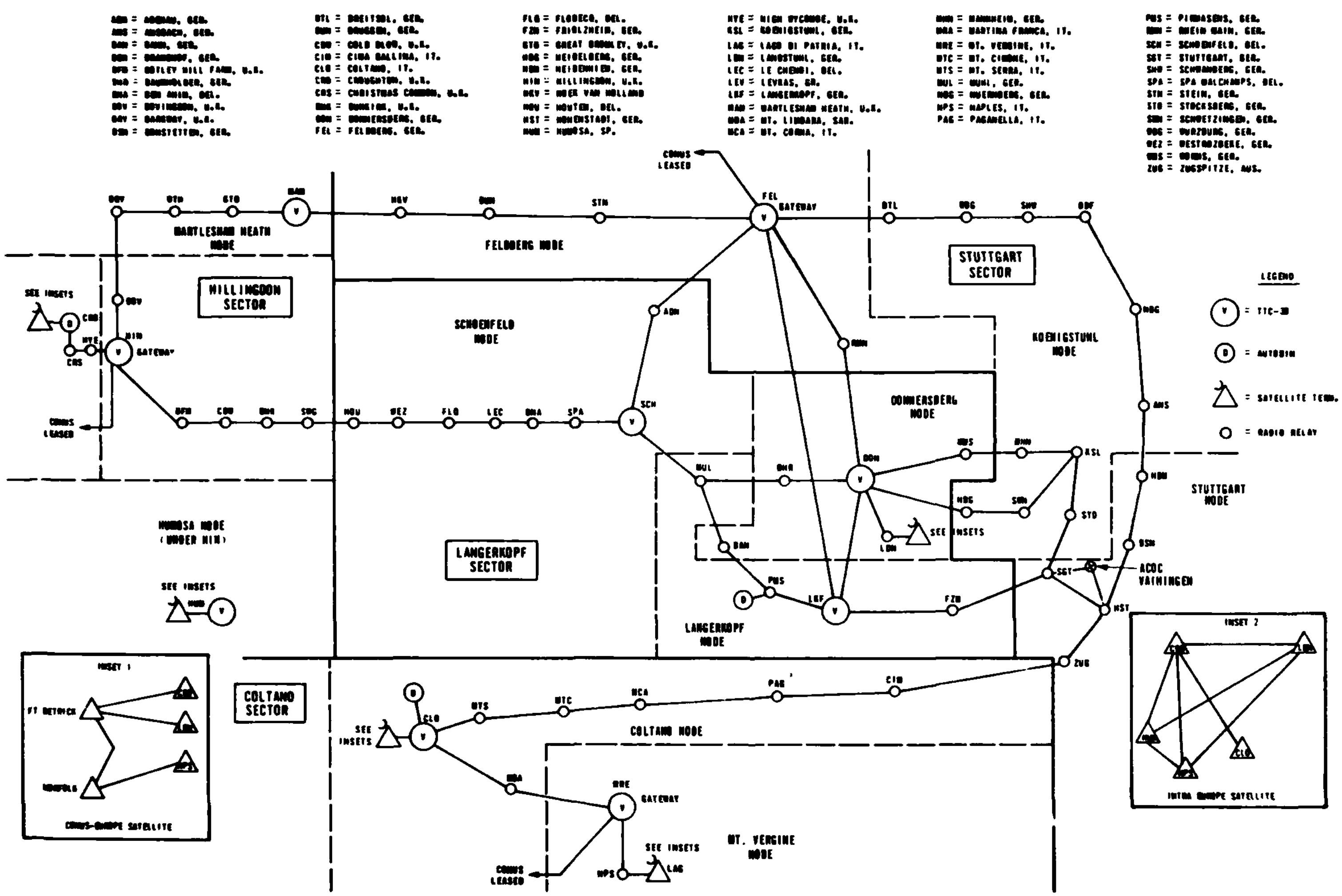


Figure 1-1. Transmission System Deployment Model

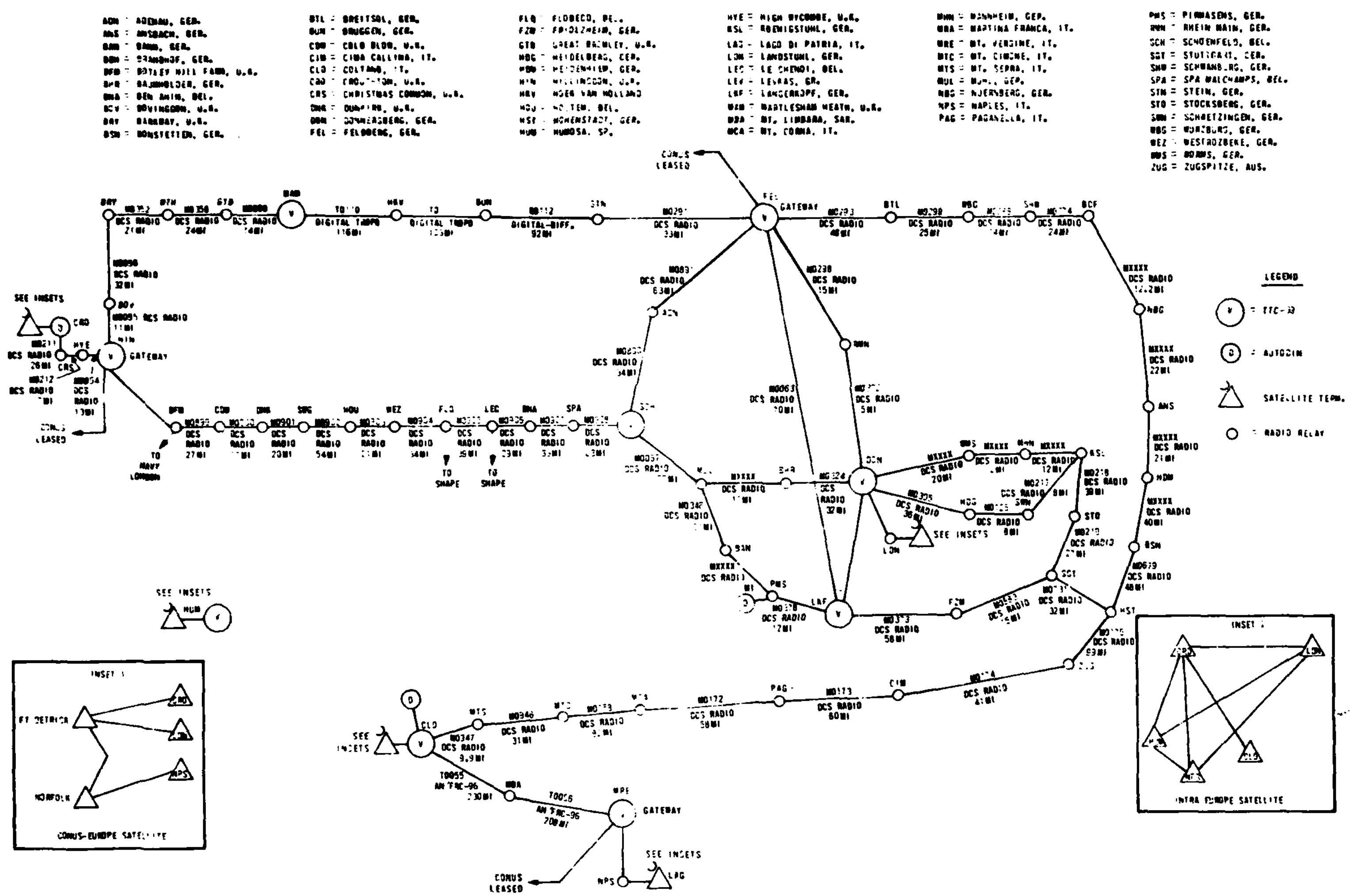


Figure 1-2. Link Detail

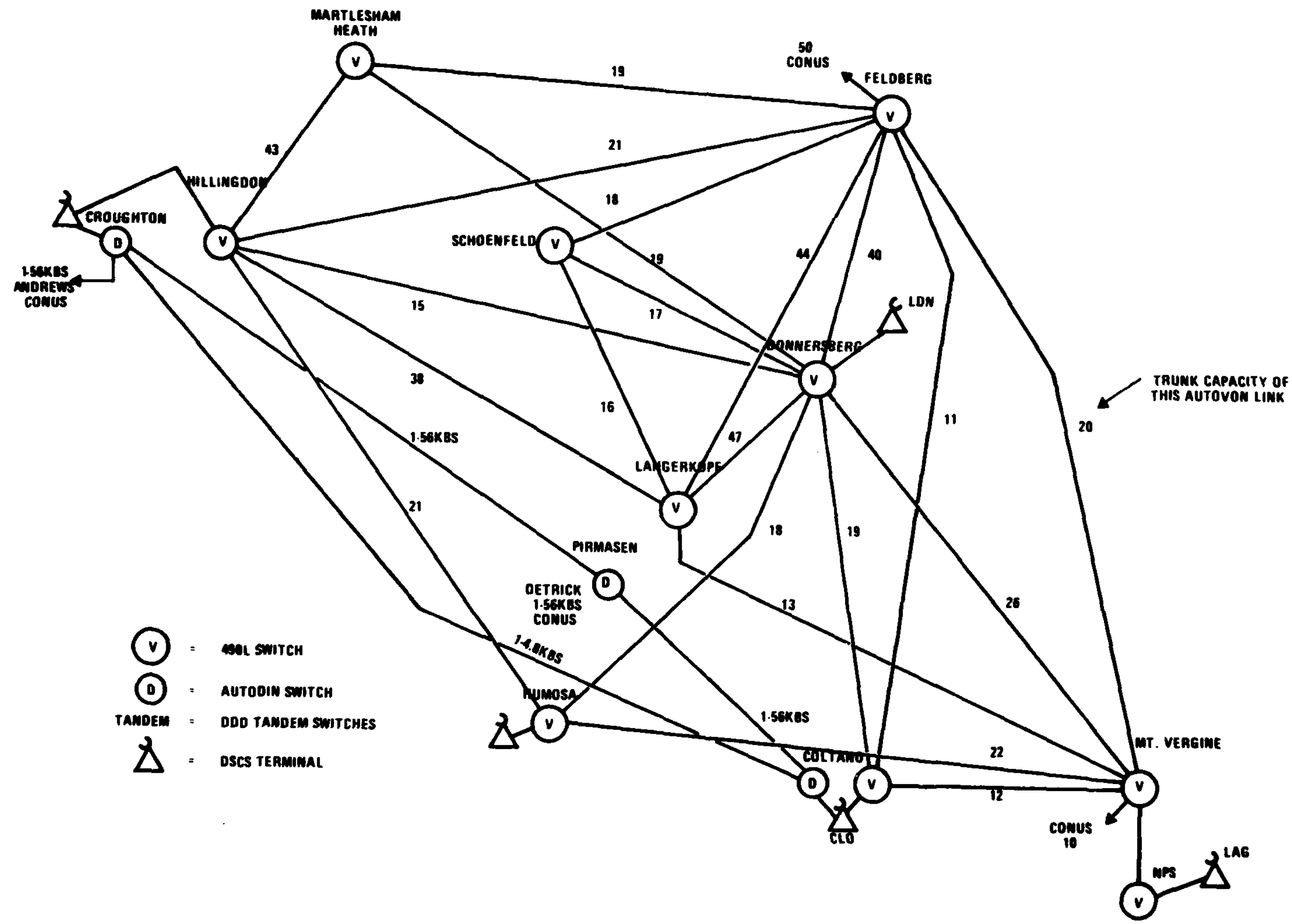


Figure 1-3. Common User Network Deployment

- Voice traffic is carried over an integrated AUTOVON/ AUTOSEVOCOM II system using AN/TTC-39 switches, to replace the current 490L switches, and SB-3865 switchboards.

Congressional action during the course of the study has made the voice network assumption inappropriate. Therefore, the later portions of the study assumed that the current AUTOVON system would remain in place, except for the removal of the Mt. Pateris switch and modifying the trunking to be consistant with the automatic secure voice communication network (AUTOSEVOCOM II) plans.

Figure 1-3 shows the resulting deployment of switches and trunks.

1.2.4 Pre-Existing System Control Components

ATEC, as specified by the ATEC 10000 specification, is assumed to be operational and fully deployed. All sites are assumed to be suitably instrumented with measurement acquisition subsystem (MAS) components to perform their monitoring function. Appropriate higher level nodal control subsystems (NCS) and sector control subsystems (SCS) are also assumed to be deployed, resulting in a comprehensive performance monitoring and stress isolation system for the terrestrial transmission system.

The satellite system is assumed to be under the control of its own control segment, as specified by the DSCS/CS specifications. Detailed control of earth terminal operation is performed by the terminal control element (TCE) while network-wide operations are controlled by the network control element (NCE). One difference between the DSCS/CS specification and our

recommendation is that we recommend integrating the operational control element (OCE) into the theatre level control function because its primary function is to be an intelligent terminal accessing the NCEs. This function could be performed by the recommended ACOC system without separate OCE hardware. The OCE therefore does not exist as a separate entity in this study.

1.3 CONTROL SYSTEM OVERVIEW

1.3.1 The Control System Hierarchy

The hierarchical relationships and telemetry interfaces between the DCS subsystems are shown in Figure 1-4. The top level of control is the defense communications agency operation center (DCAOC), where world-wide control of the DCS is exercised. Associated with DCAOC is the AUTODIN II network control center (NCC) which is responsible for world-wide control of the AUTODIN II network. A similar structure is present at the theatre level, with an ACOC exercising control over theatre wide operations and an AUTODIN II subnetwork control center (SNCC) reporting to it. The SNCC also reports to the NCC, and ACOC reports to DCAOC for management and long-term engineering purposes. Lower levels report to the ACOC, with AUTODIN II switches reporting via the SNCC and DSCS, and ATEC and AUTOVON reporting directly to ACOC. AUTOVON uses the ATEC telemetry system for reporting, but the ATEC system provides only communication service and performs no AUTOVON control function.

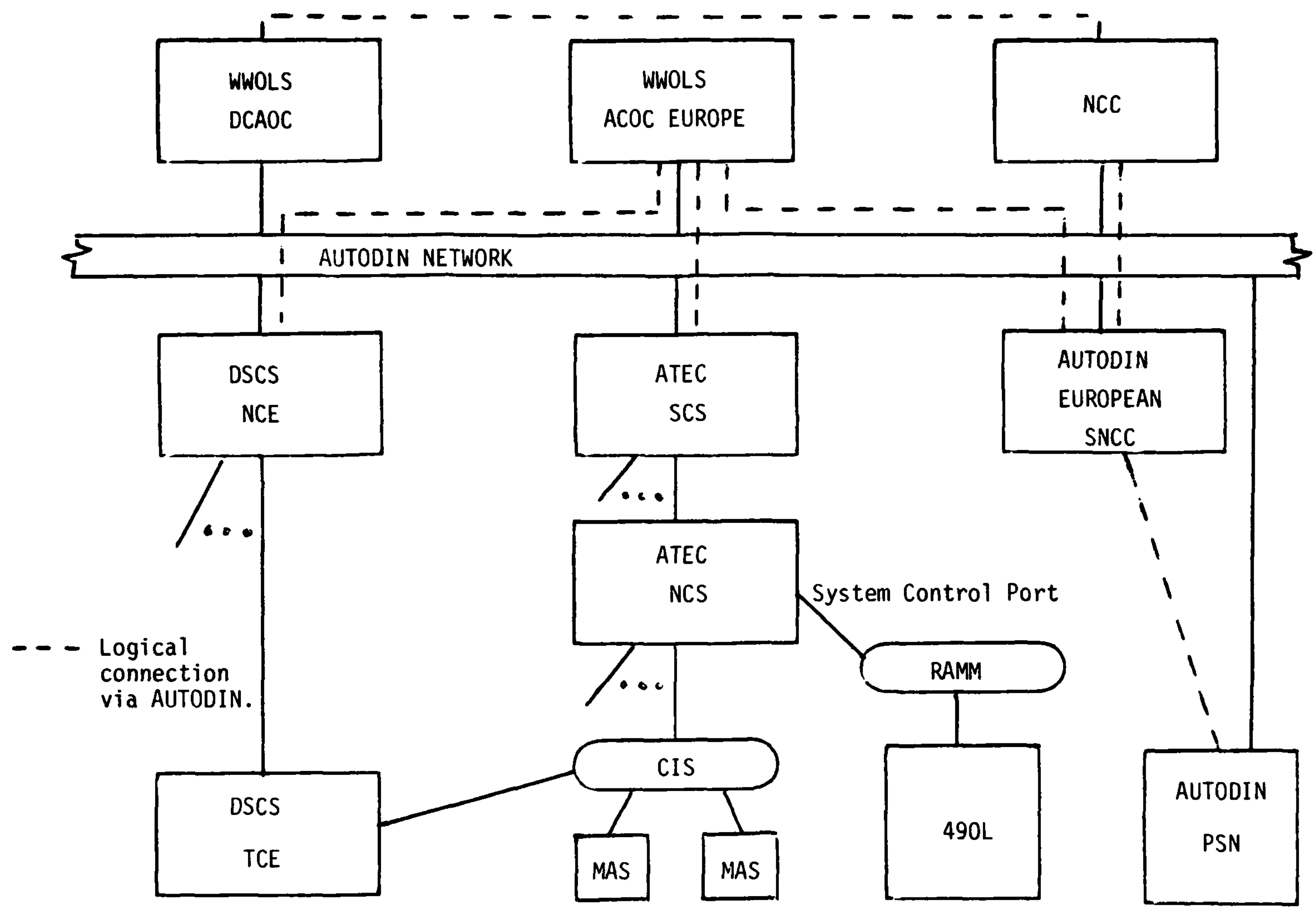


Figure 1-4. The Control Subsystem Hierarchy

A summary of the area-wide information flow recommended in this study is presented in Figure 1-5. This figure expands upon the hierarchy of Figure 1-4 and identifies the interfaces which make up the area-wide control system design. The left side of the figure details the subsystems which are present or planned for integration: AUTOVON, AUTODIN II, ATEC and DSCS/CS. Recommended additions to this subsystem hierarchy are the SNCC for AUTODIN, the rapid access maintenance monitor (RAMM) of AUTOVON and the CRU for ATEC stations. The right side of the figure describes the recommended control functions of the real-time WWOLS/ ACOC. The control functions listed under each control level identify the functions of that level in the area-wide control system. For the existing or planned subsystems, these functions are a combination of some previously defined subsystem functions and new functions required to support area-wide control.

The primary addition recommended by this study is a real-time WWOLS/ ACOC function. The ACOC performs controls requiring area-wide visibility. It also acts as a central storage and access area for performance parameter history required in planning and assessment.

Transmission control will be implemented with CRUs. These elements of the transmission system will enable time-division patching among channels of any group or link entering a DCS station. The CRU eliminates the need for all levels of multiplexer in order to patch a channel to a different multiplex group. The CRU has local control capability via a keyboard/display unit and can be remotely controlled by higher control levels via its ATEC communications interface subsystem (CIS) interface.

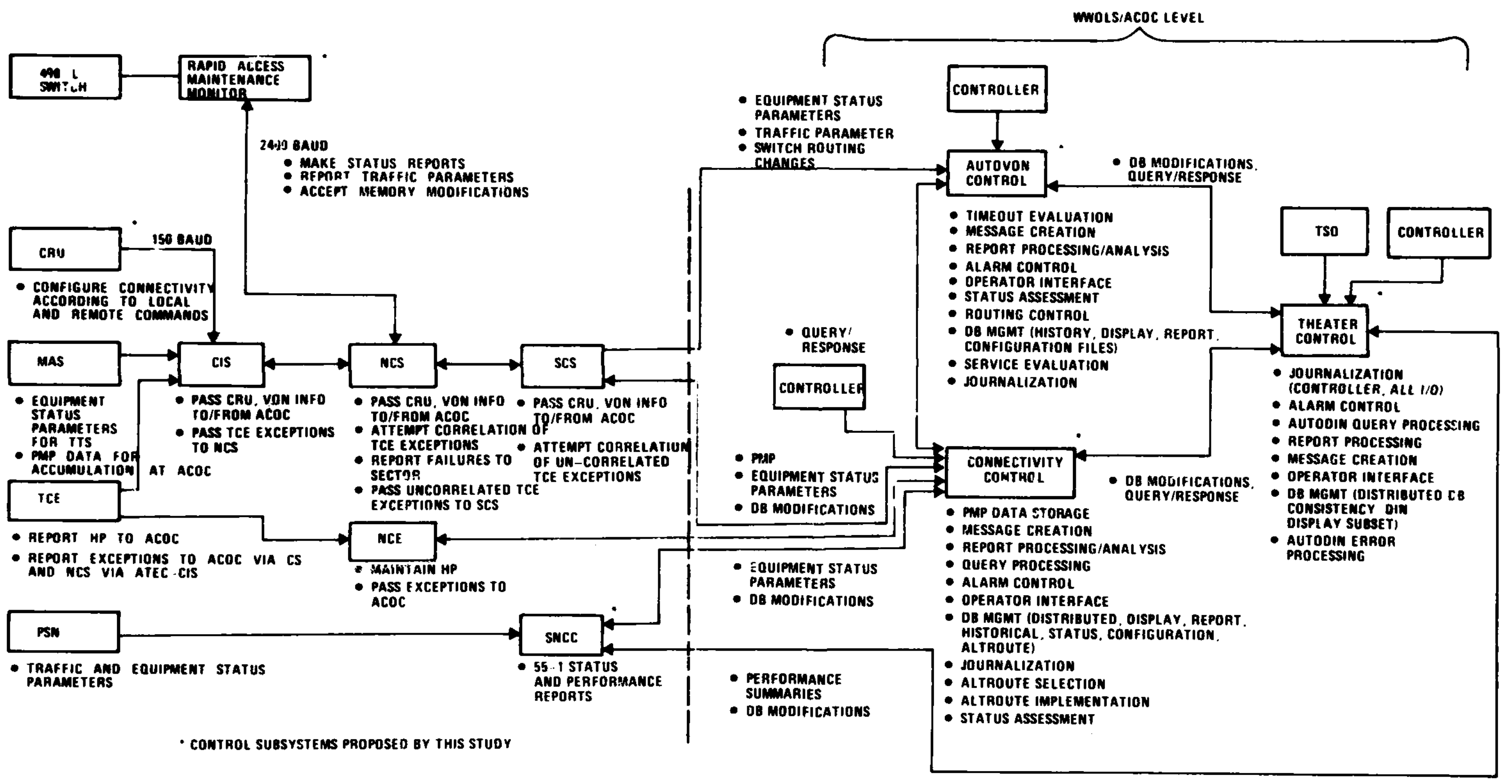


Figure 1-5. System Control Information Plan

The only addition to the AUTODIN II subsystem for implementation of area-wide control is the SNCC. This control element is identical in both function and implementation to the CONUS NCC, except that it deals only with the European theatre of the AUTODIN II network. The reasons for the addition of this element are the following:

- It provides the AUTODIN II NCC function in the theatre in case of loss of CONUS NCC or the links to CONUS.
- It provides AUTODIN II reporting to ACOC without trans-Atlantic communication from the CONUS NCC.
- It allows implementation of AUTODIN II control using an existing system design.

The SNCC will be the destination of reports from European packet switching nodes (PSNs), which will then retransmit reports to the NCC in CONUS.

1.3.2 Overview of AUTOVON Control

AUTOVON control ensures that the network carries critical subscriber traffic to the best of its ability. This does not necessarily mean optimizing the network grade of service (GOS), but it does mean at least the following:

- Providing switch routes between all sources and destinations which have physical connectivity.
- Preventing the network from traffic overloads of such a magnitude that increasing the offered traffic load results in a decrease in the carried load.

- Providing management visibility to determine the proper real-time control actions and to monitor the longer term performance of the system.

Visibility of network status is obtained by collecting parameters from the switch and providing them in a useful manner at ACOC. The TTC-39 switches specified for AUTOSEVOCOM II had extensive reporting capabilities designed into them and were adequate without significant modification. For the 490L switch, an external device must be used to sense the switch status. This function can be performed by the RAMM which is currently being deployed. New software and communications interfaces to the RAMM are required in order for it to fulfill these functions as described in Section 4.

The parameters recommended for AUTOVON control provide for comprehensive status of the network equipment and estimators of trunk and switch traffic. Detailed traffic data needs to be compiled for long-term engineering purposes, but the required smoothing time makes such data unusable for real-time control. Control can be achieved without such detail.

To provide these parameters to a controller in a useful fashion, a data base and a hierarchical set of displays are provided. By using this technique, large amounts of data can be made available to the controller, and he need only examine the data pertinent to the current problem. The hierarchical displays present a concise summary of system status at the top display level and progressively more detailed displays as the controller goes deeper into the hierarchy. This prevents overloading the controller with unrelated, needless information. Another design principle used to reduce operator workload is to identify abnormal or changed data on the displays rather than just displaying raw status parameters.

Controls which are easily implemented from the theatre level are those which modify the switch memory. The switch memory can be modified via the RAMM, without any modifications to the switch itself. It is recommended that the theatre level controller be provided with a flexible facility for changing the switch routing tables based on this capability. Two automatic algorithms which modify routine tables are also recommended.

The first algorithm is a simple form of adaptive routing. In order to limit the amount of time a call can occupy switch equipment and to prevent the use of extremely inefficient routes, AUTOVON switches are restricted to between one and four alternate route choices. This leads to the possibility that all the route choices allowed by the routing tables could be in a failed condition while some other route, although less efficient, is still functioning. The recommended adaptive routing simply modifies the routing tables in response to trunk group failures in order to provide functioning routes to all destinations as long as any connectivity is functioning. The other recommended algorithm provides a form of overload protection. It senses the loading on a trunk group over a short interval. If the trunk group was heavily loaded during that interval, all secondary and tertiary routes which contain that group are inhibited during the next interval. This tends to reserve the group for those calls which can most efficiently use it; and most importantly, it reduces the time that switches throughout the network are tied up processing secondary and tertiary routed calls which will most likely be blocked anyway.

1.3.3 Cost Summary

Budgetary costs for the hardware and software modifications or additions derived during this study are summarized in Table 1-1. Hardware costs for the additions to the RAMM and the ACOC/WWOLS system control processor are representative catalog prices for state-of-the-art hardware available off-the-shelf. The cost basis for the CRU is given in Section 4.2.1.2. The budgetary software costs include design, code, debug, and software documentation. The documentation is assumed to consist of Software Specifications Parts I and II, test plans, and user's manuals. Higher order language (HOL) software is estimated at six lines of code/day. Assembly level language is estimated at 12 lines of code/day.

TABLE 1-1. BUDGETARY COST SUMMARY

System/Subsystem	Hardware Costs (Dollars)	Software Costs (Man-Days)
AUTODIN II SNCC		5
RAMM	42,210*	178
CRU	2,830,510**	--
DSCS TCE		40
DSCS NCE		35
ATEC CIS		5
ATEC NCS		46
ATEC SCS		40
ACOC/WWOLS	93,065	3338

*See Section 4.2.2.3

**See Section 4.2.1.2

1.4 CONNECTIVITY CONTROL BENEFITS

One goal of connectivity control is to improve the circuit availability to a user under conditions of equipment degradation or failure. This study recommends that an automated altroute search algorithm at ACOC be implemented in order to reach this goal. The benefits of this control are measured in terms of a circuit availability analysis comparing the algorithm's altrouting versus current practices.

In the analysis in Report 3, some typical circuit routes were postulated and altroutes were characterized for these routes. The resulting circuit outage probability (in percent of time out) is plotted as a function of a circuit's priority in Figure 1-6.

The comparison of primary interest is between the manual search/manual patch altrouting versus the algorithm search/manual patch altroute implementation. The algorithm reduces outage probability considerably due to its rapid altroute synthesis. The manual altroute search method employs the current system of searching for an altroute from multiplexer maps and coordinating the result with other stations involved over voice or teletype (TTY) orderwire circuits.

Figure 1-6 also makes a comparison of these two altroute methods versus altrouting using a CRU at the patching stations. This CRU can receive automatically generated patching messages from ACOC and implement an altroute in significantly shorter time than manual patching. The result is reduced circuit outage probability over all priority levels of the altroute group.

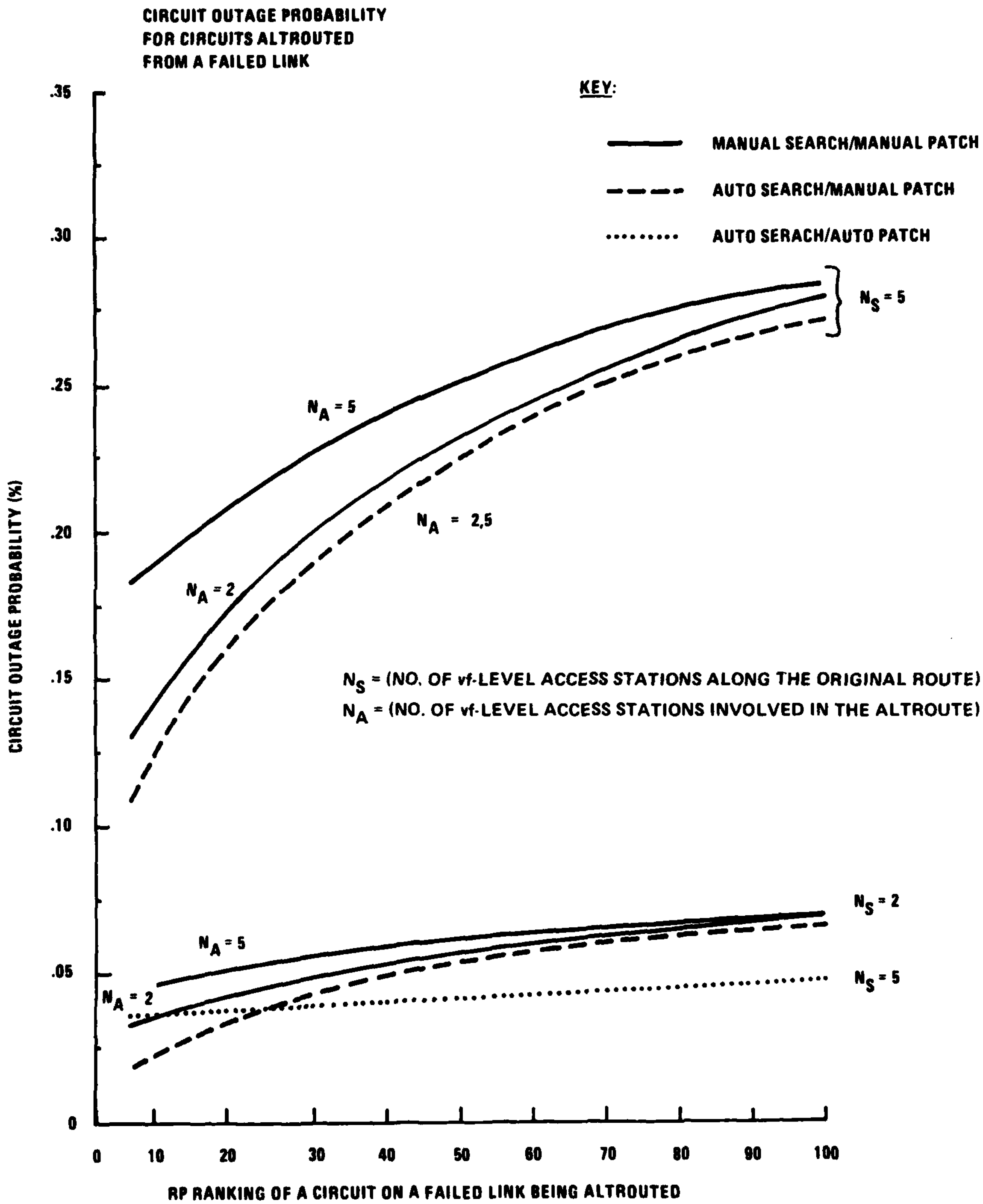


Figure 1-6. Availability vs Altroute Priority

Using central altroute control which has the current status of the network can significantly improve circuit availability by automating the search for alternate routes and removing the time-consuming human factors in the current system.

1.5 FUTURE STUDIES

During the course of this study, we identified several promising areas for further research. The primary candidate would be to demonstrate the automatic altrouting algorithms described in Reference 3.

This study has proposed algorithms which can be used to automate the altroute search control. The benefits of the use of these algorithms at the area level have been estimated. The estimates show improved service availability and possible manning reductions at stations in the DCS. The next logical step for this work is the computer programming of the algorithms presented in this study. The actual availability improvements that the algorithms can provide can then be analyzed for a variety of real network conditions. Only with the programmed version of the algorithms can this analysis be carried out for the statistically significant number of examples needed to prove the algorithm's benefits.

This task of implementing the altroute algorithms should cover all of the related subtasks in order to result in a final usable program package. The subtasks that should be completed as part of this task are:

- Establish the DCS data base for the European theatre. This data base will be needed in order to actually work realistic examples of the finished product.

- Program the actual altrouting algorithms: the main calling routines, search routines, goal station definition routine, and the cost and heuristic cost calculating routines.
- Implement the patching displays which convey the altroute plans to the area controller and patching controllers.
- Test the program package extensively over a wide variety of altroute problems to determine the package's effectiveness to provide service availability improvement.

The recommended system control depends heavily on ATEC telemetry, both for collection of parameters and for the dissemination of control commands. The survivability of the currently planned ATEC telemetry system is very limited due to its strict hierarchical structure. A study needs to be made to design a robust telemetry system for ATEC which can be fitted into the system without major changes to either the ATEC hardware or its concept of operations.

Another area which needs considerable research is the thrashing phenomenon in circuit switched networks. The basic cause and effect relationship between switch overload and decreased traffic handling ability is understood, and control actions have been heuristically defined which can contain the problem. However, there are several aspects of the problem which simply are not known.

Research is needed to determine if there is a bound on the region of network thrashing to determine if a thrashing-proof network can exist.

Heuristically, it seems that there is surely such a bound. With the rapidly decreasing cost of switch processing capability, it may be practical in the future to design networks so that thrashing cannot occur. This research should include a study of the impact of different signalling and route searching protocols on the bound in order to provide guidance for future network designs.

Another aspect of the thrashing problem is to study the transient behavior of network thrashing. It appears that the approach to a thrashing condition can occupy a significant time span, especially if the heuristically designed controls are employed in an attempt to prevent thrashing. Further, when the traffic load is reduced, the network does not return to normal immediately but stays in a reduced capacity state for some time after which the network spontaneously switches to the normal state. The factors which affect this transient behavior are not understood. An understanding of these factors would provide guidance toward designing traffic controls for old networks and signalling/routing protocols for new networks.

Relative to old networks, two traffic control algorithms were recommended but not tested during this study. If the 490L network is going to continue in use, these algorithms should be tested by accurate traffic modelling and/or simulation. It is heuristically clear that these algorithms will significantly increase the capability of the network under stress conditions, but we were unable to demonstrate exactly how much within the scope of this study.

The last item relative to AUTOVON which needs further study is the RAMM. Several functions have been attributed to the RAMM on the basis of fairly vague documentation and a couple of clarifying telephone conversations with RAMM's developers. A detailed study of the RAMM design, its interface

with the 490L switch, and how RAMM fits with future plans for the 490L system needs to be undertaken to define in detail what role the RAMM can plan in the system control.

In the analysis of manpower and response time, we ran into the problem that the available data is based on the pre-ATEC, pre-DEB DCS. Other studies available to us extrapolated this data so that we were able to draw some conclusions. However, when ATEC and DEB are fully operational, the network operating characteristics will be radically changed from the last observations that were actually made. As these subsystems are introduced, careful accounting can be done by either time reporting or observation, but studies should be done on a regular basis. These studies will allow the refinement of manpower prediction models and will permit the identification of fruitful areas for further automation or other engineering action.

SECTION 2

TRANSMISSION SYSTEM CONTROL

2.0 CONTROL SYSTEM OVERVIEW

This section summarizes the transmission control elements that have been recommended in the previous reports of this study. The transmission control system consists of the following subsystems:

- ATEC
- DSCS/CS
- ACOC/WWOLS

Of these subsystems, the real-time WWOLS function is the element primarily discussed in this study. The other elements of the network control are already planned and are fairly self-contained in their functions. The interfacing of these elements to ACOC/WWOLS is the focus of this study. Therefore, this summary will deal with these new control interfaces to ACOC.

Figure 2-1 is a matrix of interfaces versus existing subsystems. The transmission subsystem elements are listed as one axis of the matrix. The elements of control system definition are the other matrix axis. These elements are the following:

- Parameter collection--the network parameters that are of use for controls originating at or planning at ACOC.

	Parameter Collection	Parameter Communication	Parameter Analysis	Control Implementation
ACOC/WWOLS		X	X	X
DSCS/CS				
o NCE		X		
o TCE	X			X
ATEC				
o SCS		X		
o NCS				
o Stations	X			X

Figure 2-1. System Control Design Elements for the DCS Transmission System

- Parameter communication--communication path, message rate.
- Parameter analysis--processing performed on the data by ACOC.
- Control implementation--selection and physical actuation of controls.

The crosses on the matrix of Figure 2-1 define those control subsystems which are involved in each element of the control system designed in this study. The matrix intersections also define sections of discussion to follow which define the control system.

2.1 PARAMETER COLLECTION

2.1.1 ATEC Parameters

The ATEC subsystem in the mid-1980's DCS will be the primary source of parameters for the terrestrial portion of the DCS network. The categories of parameters that are useful to ACOC from this subsystem and the reason for the need is summarized below:

- Equipment status information--allows ACOC to be aware of the state of the transmission facilities that may be used in creating altroutes.
- Fault isolation information--brings failed network services to ACOC visibility so that ACOC can aid in altroute generation.

- Connectivity updates--provide ACOC wit current routes for circuits or trunks. Needed for route planning and administration.
- 310-55-1 "Q-line" data--station measurements which can be used historically to evaluate DCS transmission system performance.

Figure 2-2 cross-references these parameter categories for ACOC visibility with the ATEC parameters to fulfill the needs of ACOC. The parameters selected in Figure 2-2 originate at the station level of ATEC in the MAS units. The first four parameters are direct results of hourly MAS measurements which are logged into history files at node and sector. These history files of parameters can be trended by mean and standard deviation over various time periods. ATEC can store these histories for up to a month. Thus, these first four parameters' summaries should be sent to ACOC on at least a monthly basis as quality control summary data.

The last four parameters listed in Figure 2-2 are related and have to do with status monitoring of the transmission system. The fault isolation activity is an inter-level cooperative activity of ATEC to determine the exact location of alarms or out-of-tolerance equipment reported via the quality control sequences or equipment alarm monitoring. The fault isolations give the ACOC control the data needed to begin altroute searching. The alarm and monitoring parameters from ATEC are less refined parameters but provide the ACOC data base with current status information on possible preemptable segments in the network. ATEC data base maintenance provides ACOC with current connectivity data to show how the transmission medium is used for specific services. The timeliness

ACOC Parameter Catagories

Connectivity updates	Equipment status information	Fault isolation information	Quality control data	
			X	Mean & lowest RSL history (TDM system) (3.2.1.1.4)*
			X	Baseband degradation history (TDM system) (3.2.1.1.4)
			X	Time duration history of all multiplex levels degradations (TDM systems) (3.2.1.1.4)
			X	Radio transmitter power data history (3.2.1.2.5)
X	X	X		Fault isolation reports (3.2.1.2.4)
			X	Automatic quality control test sequences (3.2.1.3)
	X			Equipment and facility alarm monitoring (3.2.14)
X				Data base management (3.2.1.12.5)

*Refers to ATEC 10000 specification sections.

Figure 2-2. ACOC Parameter Needs vs ATEC Data

of the ACOC data base is crucial to its altroute and normalization control activities and system administration.

2.1.2 DSCS/CS Parameters

The DSCS control system will provide the needed parameters for management of the satellite portion of the DCS. The four parameter categories defined in Section 2.1.1 for the ATEC parameters apply to DSCS parameters as well since the ACOC function is the same for all transmission segments in the DCS.

The method of correlating the ACOC parameter categories with the actual parameters available from DSCS/CS is done with the cross-reference of Figure 2-3. The parameters chosen from the full DSCS/CS parameter list (Report 2, Section 5.4) were selected because they primarily deal with the service-oriented view of the ACOC mission. They report the status and availability on a go/no-go basis. ACOC must provide service to users over the DCS facilities. The details of the transmission facility state are not important to real-time control, only the availability for use right now. The only need for specific equipment status data is the historical need to see how the network is functioning over time in an effort to aid in planning and assessment.

The first three parameters selected from DSCS/CS are basically summary items. They give status data which is condensed from more specific parameter reports within the DSCS/CS. These parameters will be the primary source of go/no-go data for ACOC from which data base status

ACOC Parameter Categories

Connectivity update	Equipment status information	Fault isolation	Quality control data	DSCS/CS Data Available
	X	X		Link performance reports
	X	X		Equipment status reports
	X	X		Text messages
X				Spare resources
X				Configuration updates
				Calibration test data:
			X	o Received C/kt (downlink)
			X	o Transmit EIRP (uplink)
			X	o Satellite beacon frequency error
			X	o Satellite translator frequency error
			X	o Pilot signal strength--all terminals

Figure 2-3. ACOC Parameter Needs vs DCSC/CS Data

updates are made. In addition, these parameters can be used within ATEC to aid in fault isolation when a route passes over a satellite link.

The configuration updates supplied by the DSCS/CS will provide ACOC with current connectivity data for the subset of the total DCS network which is satellite links. Spare resource data will give current capacity data concerning the satellite links. Both items are needed for route planning over DSCS links.

The remaining parameters are generally calibration test data. They will be used at ACOC to study equipment performance in a historical way for planning and assessment purposes. Calibration test data is utilized by DSCS/CS elements on a real-time basis for control and management of satellite operations. The parameters selected for use at ACOC are chosen to reflect system performance rather than site performance. The NCE should be the point where the data is collected and held for transmission to ACOC.

2.2 PARAMETER COMMUNICATION

2.2.1 ATEC Parameter Communication

2.2.1.1 The Physical Communication Links--The ATEC communication system is clearly defined in Reference 4 (ATEC 10000). The primary links (ACOC, sector, node, station) are 2400 bits per second (BPS), full duplex, dedicated links between control levels in ATEC (see Figure 2-4). Stations at MAS sites will communicate with one another over 150 baud dedicated links. The ACOC system design will have a 2400 BPS AUTODIN II

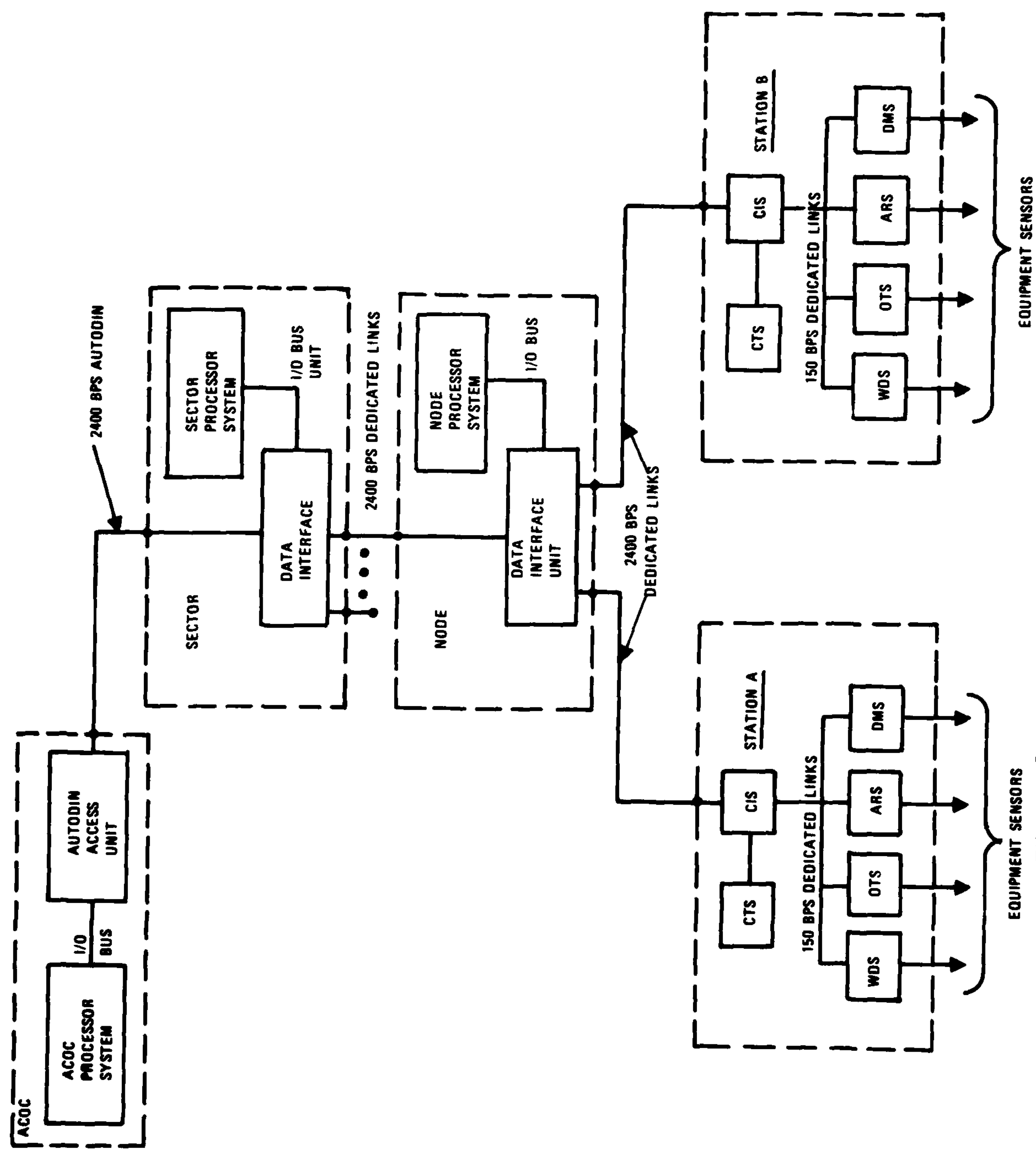


Figure 2-4. The ATEC Message Channels

access line to be used to connect ACOC with each sector. Using AUTODIN II rather than dedicated sector ports will guarantee the use of redundant and adaptive routing of messages in either direction. The message format for the ATEC links is given in Figure 2-5. For consistency, the messages between ACOC and ATEC should be sent with the ATEC message format embedded within the AUTODIN II format. This would allow the messages of lower ATEC levels to be transmitted to ACOC via sector without format changes and vice versa.

2.2.1.2 The Message Rates for ATEC Parameter Reporting--The messages required from ATEC over the channels to ACOC fall into two classes:

- Immediate update messages
- Historical parameter transfer messages

In the first class, the critical item is the bit rate required under stress conditions of known message quantity and time limitations. The second class of messages has no short-term time limit for transmission. The critical parameter is the total character count in the messages, to determine the light load transmission and processing time. The last four parameters of Figure 2-2 fall into the first class; the first four parameters are in the second class.

Immediate update messages include data base updates, equipment status, and fault isolation parameters. These parameters yield real-time control actions. Thus, these parameters must be timely and messages must be sent to ACOC on parameter change.

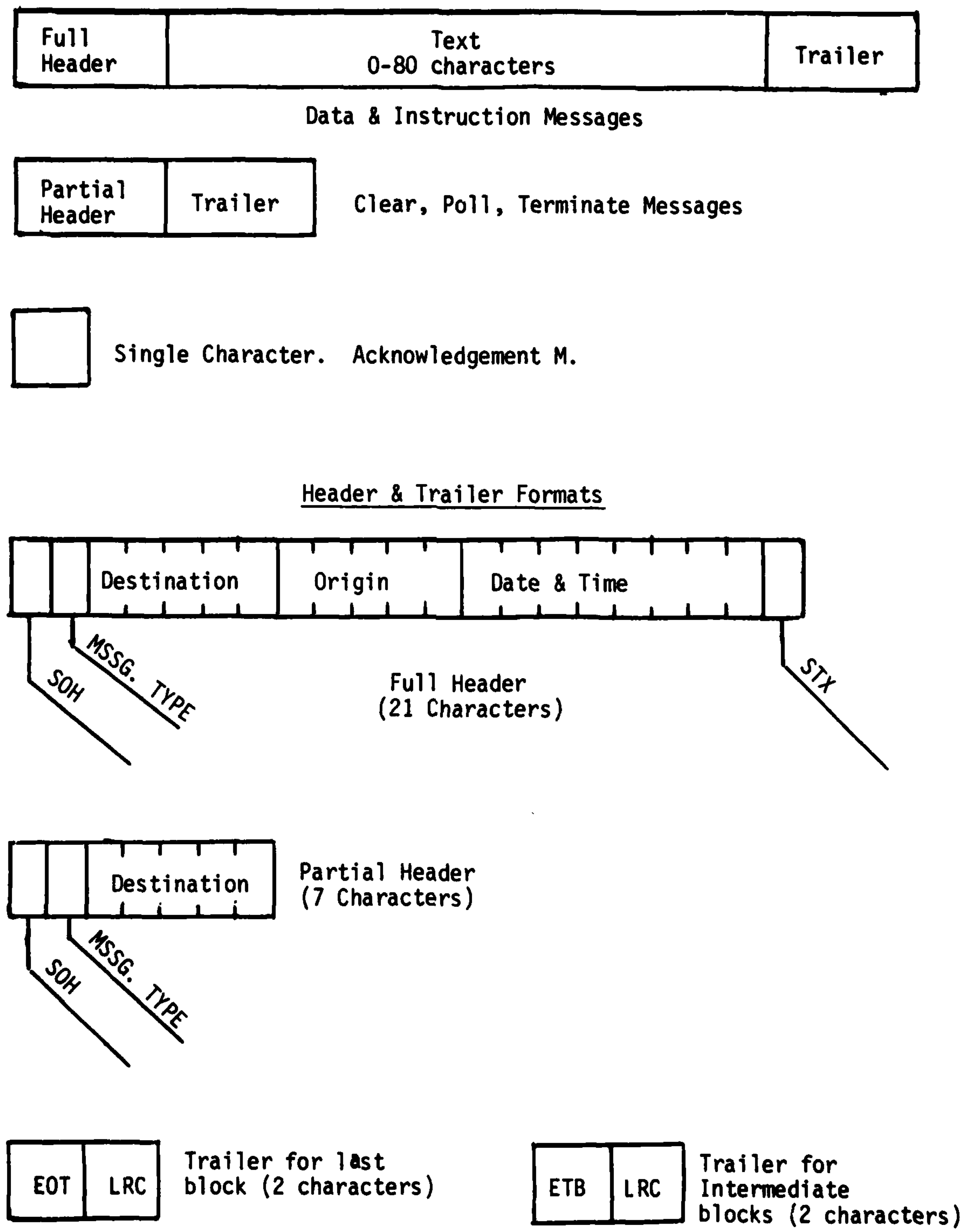


Figure 2-5. The ATEC Message Format

An analysis was made in Report 2 (Section 3.2.2) to estimate the message reporting load of these messages. This analysis takes the ATEC 10000 specification MAS reporting load as a starting point. The messages are assumed to be reported up the ATEC control hierarchy and are consolidated as they proceed. Assumptions are made as to the report consolidation at each level in Report 2. The result of the analysis is that an estimated 195 BPS flow from the sectors to ACOC are required to handle the update messages. This estimate was made for the European ACOC and results in an average of 50 BPS per sector. The ATEC 10000 specification sets 10% of the 2400 BPS sector/ACOC link capacity as a design capacity for messages under design stress. Since status reporting is the primary function of the sector/ACOC message channel, there appears to be more than enough message capacity at sectors to transmit the update parameters to ACOC from the ATEC hierarchy.

The summary of routine transmission link tests makes up the historical parameter class. Report 2 (Section 5.3) estimates the message size per summary as 84 characters per link. With 410 links in the European ACOC, the character transfer of all of the historical parameters to ACOC would result in a transfer message of 138,000 characters. This load may occur daily, weekly, or monthly depending on the ACOC historical requirements for this data.

2.2.2 DSCS/CS Parameter Communication

2.2.2.1 Physical Communication Links--Two new communication links are recommended to utilize DSCS data.

- The NCEs will interface to WWOLS via AUTODIN II. Using AUTODIN II guarantees that messages in either direction will use redundant and adaptive routing.

- The TCEs will interface the ATEC station over voice orderwire and 150 BPS CIS interfaces. TCE/CIS messages will be reported in ATEC CIS format to provide the status of DSCS transmission segments on a local level.

2.2.2.2 Message Rates for DSCS/CS Parameter Reporting--The messages sent to ACOC from the DSCS/CS are shown in Table 2-1. Those listed as 24-hour intervals are historical parameters. The others are required for real-time control and are reported on an immediate update basis.

Table 2-1 details the message sizes for the DSCS/CS parameters to be sent. The details of the sizing are to be found in Report 2 (Section 5.4). In order to determine whether these parameters can be transmitted in real-time, a stress scenario like the one adopted from the ATEC 10000 specification was developed.

The stress scenario for DSCS/CS parameter message rate estimation assumes that the following messages are a message group which must be transmitted to ACOC as part of a critical update for control:

- One link performance assessment initial and follow-up report

- One equipment status initial and follow-up report

TABLE 2-1. DATA FLOW, NCE/WWOLS

	Control	Long Term	Trendable	Stress Sensitive to	Interval	Messages/ Day	Characters/ Messages	Characters/ Day
1. Link performance assessment, Initial report	X		NO	Satellite	By exception	2	67	134
2. Link performance assessment, Follow-up report	X	NO		Transmission System Failure	By exception	4	103	412
3. Link performance summary		X	NO		24 hours	30	33	2490
4. Equipment status, Initial report	X	X	NO		On change	150	77	11550
5. Equipment status, Follow-up report	X	X	NO		On change	225	103	23175
6. Calibration data		X	NO		24 hr summary	150	48	28800
7. Alarm messages	X		NO		On occurrence	(Part of equipment status)		
8. Text message	X		NO		On occurrence	30	250	60000
9. Configuration updates	X		NO	N/A	On occurrence	20	100	2000
10. Spare resources	X		NO	N/A	On change	60	46	2760
								131,401 Characters/ Day

- One text message elaborating on a failure
- One configuration report related to a failure

This message sequence might be caused by an equipment degradation which caused a link capacity reduction and some channel reconfiguration around the problem. This data would be needed by ACOC for updating its data base in anticipation of fault isolation reports from ATEC regarding circuits carried partially by the degraded satellite link. A reasonable time to require this type of information to be available at ACOC is assumed to be one minute.

From Table 2-1, the message group consists of a total of 5754 bits. To transmit this group over one minute, 96 BPS is needed. This bit rate is well within the 9600 baud capabilities specified by the DSCS/CS specifications for the NCE/OCE interface.

The messages crossing TCE/CIS interface are a subset of the messages crossing the NCE/ACOC interface (see Table 2-2). This information provides ATEC condensed status data in order to enable fault isolation when a trunk or circuit uses a satellite segment. The message group of the stress scenario presented earlier sends 4954 bits to the local ATEC station. To meet the 60-second time frame for reporting, 82 BPS transmission is required. The TCE/CIS link has a capacity of 150 BPS, which is adequate for reporting of real-time updates to ATEC from a TCE.

Historical parameters from DSCS/CS will include the link performance summary and the calibration test data (see Table 2-1). These parameters are intended only for planning and assessing functions at ACOC and will be sent over the NCE/ACOC link. Table 2-1 shows the estimates for each

TABLE 2-2. DATA FLOW TCP/CIS

	Control	Long Term	Trendable	Stress Sensitive to	Interval	Messages/Day	Characters/ Messages	Bits/Day
1. Link performance assessment, Initial report	X		NO	Satellite	By exception	1	83	83
2. Link performance assessment, Follow-up report	X		NO		By exception	2	103	206
3. Equipment status, Initial report	X	X	NO	System	On change	30	83	2490
4. Equipment status, Follow-up report	X	X	NO		On change	45	103	4635
5. Text message	X		NO		On occurrence	6	250	1500
								8914 bits/day .10 bits/second

summary of this historical data, 31,290 bits total. The estimation of these message sizes is based upon an assumption of 30 satellite links under the NCE control and 15 satellite terminals (see Report 2, Section 5.4 for details).

2.3 PARAMETER ANALYSIS

2.3.1 Data Base Maintenance

The primary use of parameters received from the transmission control subsystems is the maintenance of the ACOC connectivity data base. The connectivity data base design for the ACOC has been presented in Report 2 (Section 3.7). Figure 2-6 summarizes the data base file types and their linking relationships. The status and connectivity updates provided by both ATEC and DSCS/CS reports are the raw data with which the data base is kept current. The station, link, trunk, and circuit files in the data base are updated as new connectivity data is received by ACOC. The ACOC software translates connectivity reports into changes in all files in the data base which are impacted. Fault reports cause the ACOC processor to generate a standard fault report file for the data base. In addition, this new file is linked to the station, link, trunk, and circuit files which the fault impacts.

The data base update is crucial to further analysis and control activities which ACOC carries out. The displays from which ACOC personnel obtain network visibility are a reflection of the data base contents. Circuit or trunk altrouting relies upon current connectivity and status data at ACOC to search out operational routes.

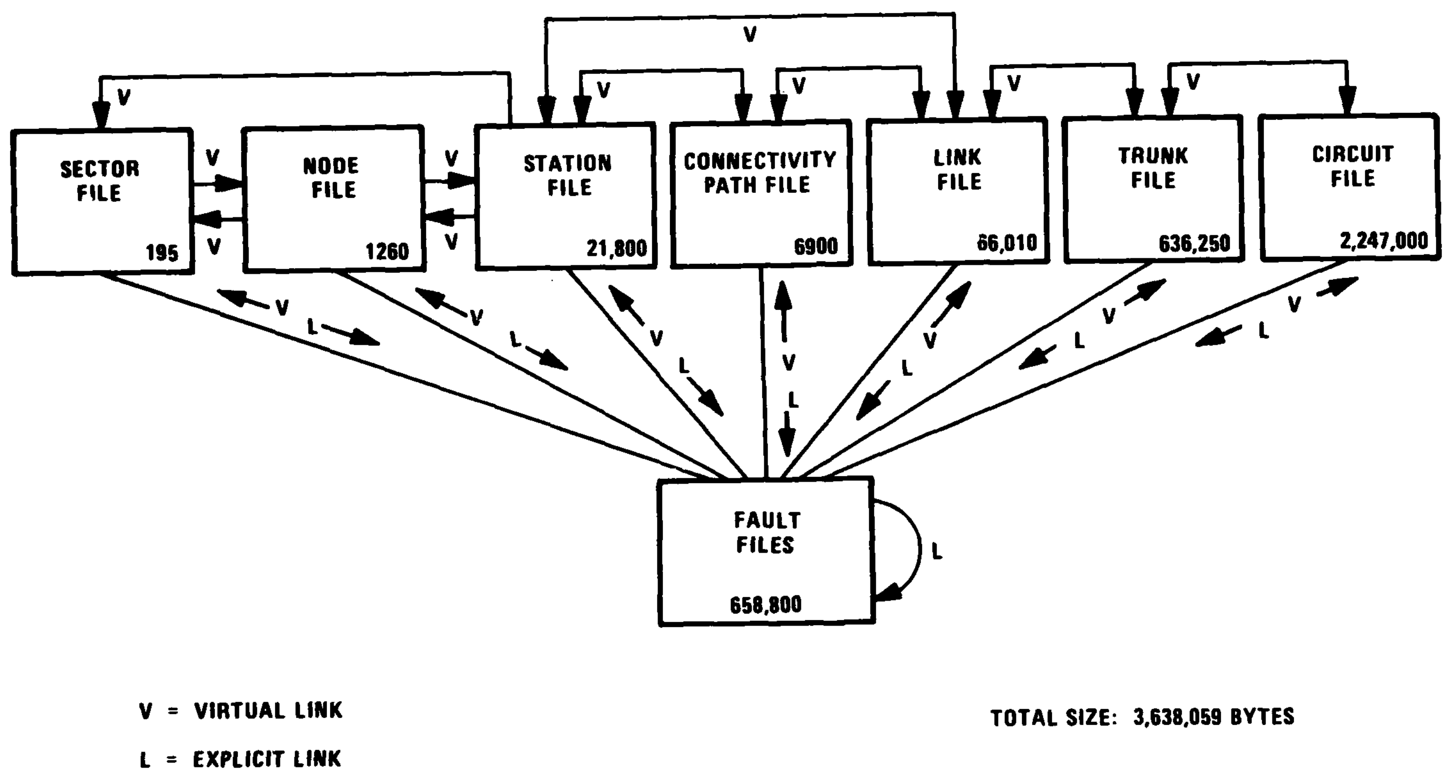


Figure 2-6. Data Base File Linking

2.3.2 Altroute and Normalization Job Queueing

The data required to set up the job queues for the altrouting and normalization control activities require the use of fault isolation reports and fault file removals (see Report 3, Sections 2.6.1 and 2.6.6). When ATEC reports a fault isolation, the trunks or circuits involved are placed in a restoral precedence (RP) ranked queue for altrouting. The segments defining the failed and intact segments of the normal route are defined. The altroute job is then ready for the altroute search. The removal of all fault files from a circuit or trunk keys the normalization job queue to set the circuit or trunk up for normal route restoration. These activities are direct parameter analysis functions which are implemented in software at ACOC.

2.3.3 ACOC Displays

All data in the ACOC data base is conveniently available for personnel using the system. Displays of network connectivity and status aid in new route planning. The historical data provided by network equipment test reports can be used to assess the field performance of equipment and aid in planning for new or additional equipment requisitions. These and other displays support any activity which ACOC personnel might be required to perform.

A summary of the proposed ACOC display hierarchy is given in Figure 2-7. Figures 2-8 through 2-12 show examples of some of these displays. Examples of the displays in the altroute plans class are shown in Section 4 of this report. This section will describe the content of each display. In addition, we will discuss the linking which should exist between displays to aid in using them to their fullest.

Displays fall into two catagories: summary and detail. Each summary display has an operator entry field to access detail displays listed in the summary (Figure 2-8). In addition, the detail displays have entry fields for accessing the display's summary display and related displays in the display class (see Figures 2-9, 2-10 and 2-11). In this way the operator has a simple and logical display access method. The displays of all classes also have an annunciator field similar in function and operation to that proposed for ATEC displays (see Figures 2-8 through 2-12). The field has a flashing annunciator character for each class to indicate an addition or change in any display in the class. Entering a character into the entry field immediately calls the summary display. The new entries themselves would have a "new entry" flashing character to emphasize their presence the first time the summary is accessed after the new entry is made.

The display classes and their content are summarized here to set some minimum design guidelines:

Connectivity Path Status:

- Connectivity Path Status Summary: A graphic display of the DCS network (Figure 2-8) giving status warnings via flashing characters on a link or station.
- Critical Connectivity Path Disturbance Summary: Lists all critical transmission media in the network which are failed in order of importance and outage time.
- Critical Connectivity Path Disturbance Detail: The details of transmission failures such as failure cause, RPs impacted, etc. are given in this display (see Figure 2-9).

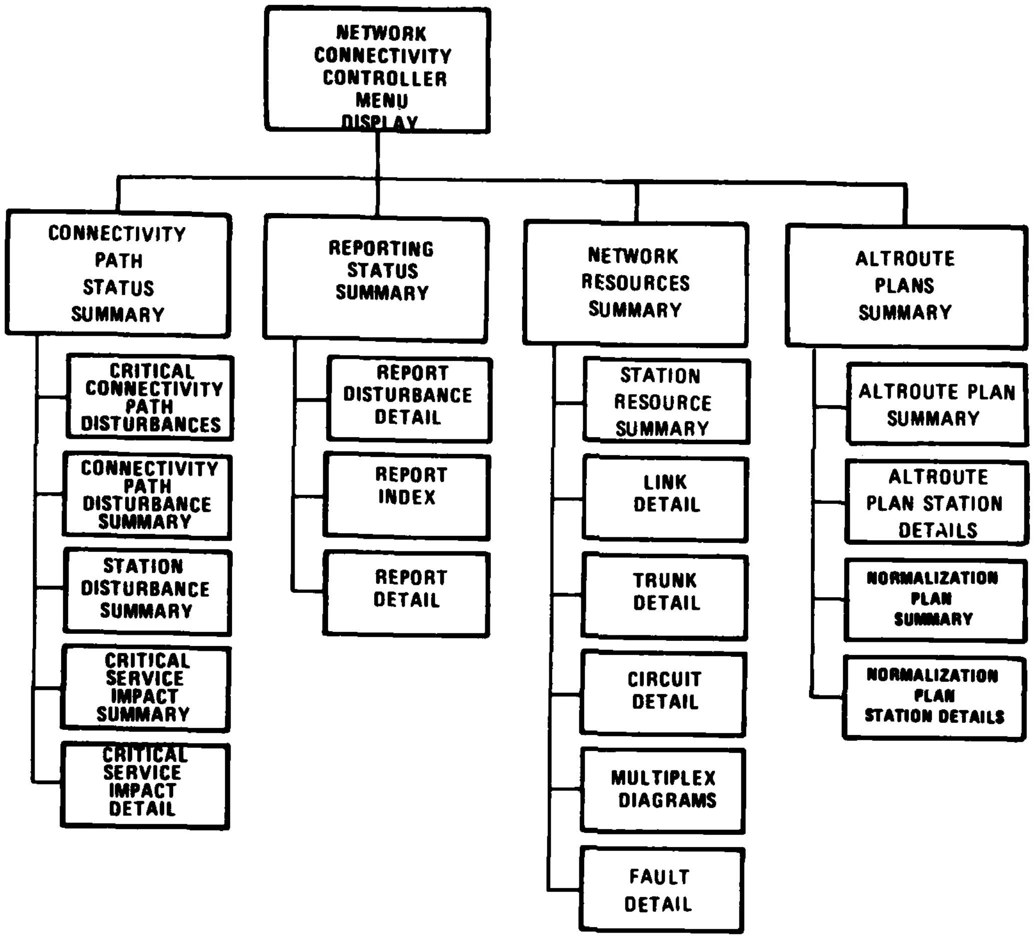
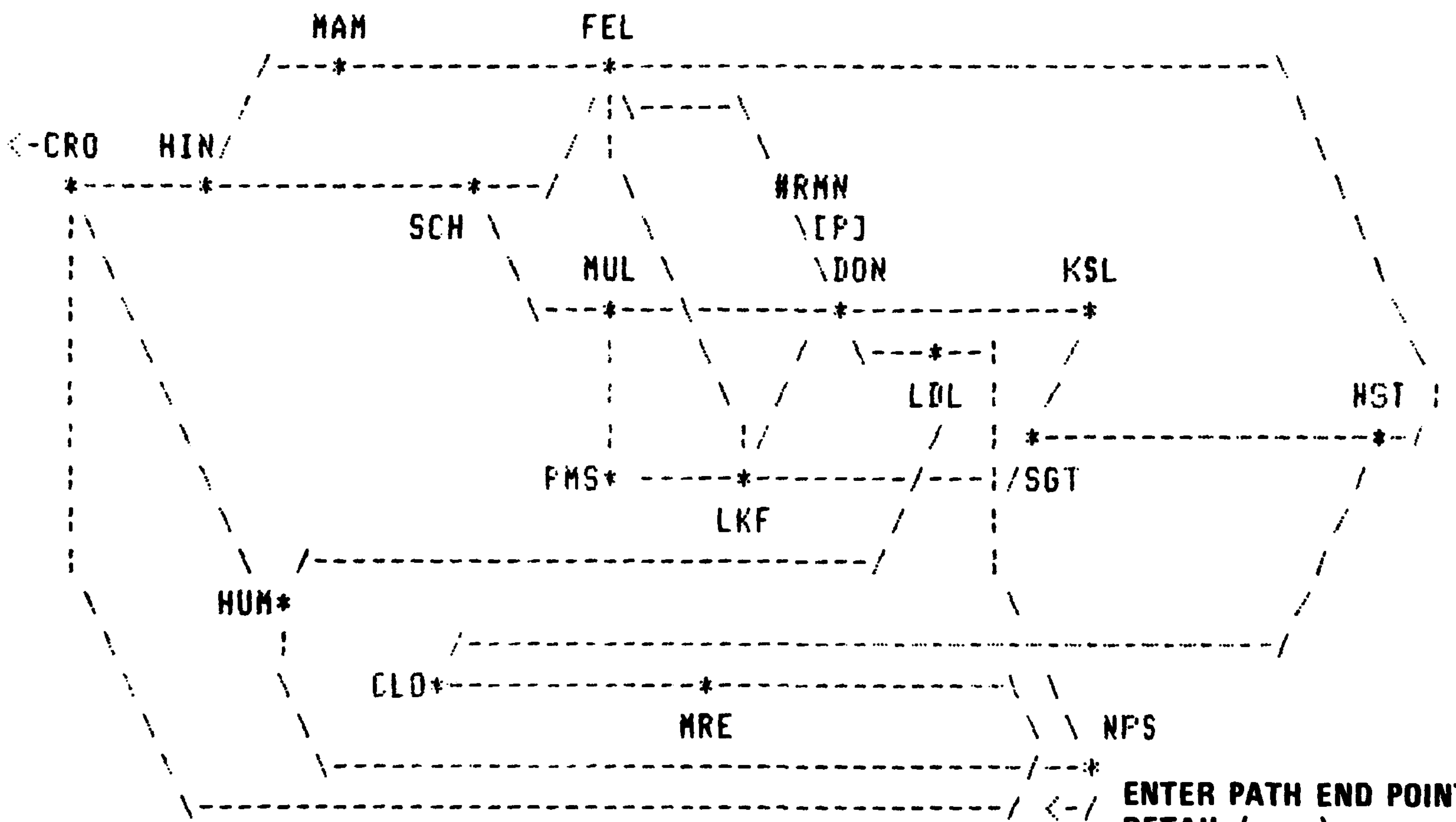


Figure 2-7. Network Connectivity Controller Display Hierarchy

CONNECTIVITY ■ ( ) REPORT ■ ( ) NETWORK RESOURCES ■ ( ) ALTROUTE PLANS ■ ( )

CONNECTIVITY SUMMARY



ENTER PATH END POINTS FOR DETAIL (–)

Figure 2-8. Connectivity Summary Status Display

CONNECTIVITY■ ( ) REPORT■ ( ) NETWORK RESOURCES■ ( ) ALTROUTE PLANS■ ( )

DON-FEL CONNECTIVITY PATH DISTURBANCE DETAILS

DON — M0372 — RMN — M0375 — FEL   HIGHEST RP OOs: 2

2 GRPS – R   2 GRPS – R

RPRT NO.	DEG	SEV	IDENT	LOC	SG	G	CH	COMMENTS	ETR	TIME
12	R	GP	44JM08	DON/ FEL	B	6	ALL			0748
6	R	GP	44JM09	DON/ FEL	B	7	ALL	EQPT—DON	0030	0730

ENTER NUMBER TO OBTAIN DISPLAYS LISTED BELOW 3

[1] CONNECTIVITY PATH SUMMARY
[3] CIRCUIT IMPACTED

Figure 2-9. Connectivity Path Detail Display

CONNECTIVITY■ ( ) REPORT■ ( ) NETWORK RESOURCES■ ( ) ALTROUTE PLANS■ ( )

CRITICAL SERVICE IMPACT SUMMARY

CONNECTIVITY PATH: DON–FEL

SEVERITY: 2 GROUPS

DEGREE: RED

QTY	RP	NETWORK	SERVICE
4	1	AUTOVON	ISTs
8	2	AUTOVON	ISTs
6	2	DEDICATED VOL.	
8	2	TTY	

ENTER NUMBER TO OBTAIN DISPLAY LISTED BELOW

[4] IMPACT LIST
[1] CONNECTIVITY PATH SUMMARY
[D] ASSOCIATED DETAIL IMPACT DISPLAYS

Figure 2-10. Critical Service Impact Summary Display

CONNECTIVITY■ ( ) REPORT■ ( ) NETWORK RESOURCES■ ( ) ALTROUTE PLANS■ ( )

REPORT INDEX

1. SCHEDULED REPORTS
2. DAILY REPORTS
3. Q–LINE REPORTS
4. OUT–OF–SERVICE REPORTS

TO REVIEW REPORT ENTER NUMBER ____ STATION ID ______
LINK ID ______
TRUNK ID ______
CIRCUIT ID ______

Figure 2-11. Report Index Display

CONNECTIVITY■ ( ) REPORT■ ( ) NETWORK RESOURCES■ ( ) ALTROUTE PLANS■ ( )

REPORTING DISTURBANCE DETAIL

REPORTING DISTURBANCE DETAIL   STUTTGART SECTOR

STATUS	TYPE OF REPORT	NODE	TIME LAST RECEIVED	COMMENTS
OVERDUE	KEEP ALIVE	FELDBERG	0729	LINK OUT – REPORT 092

Figure 2-12. Reporting Disturbance Detail Display

- Critical Service Impact Summary: Lists the high priority circuits or trunks impacted by current failures (see Figure 2-10).
- Critical Service Impact Detail: Identifies details about the circuits or trunks of high priority which are impacted by current failures. Lists items such as user, phone number of user, critical normalization plan, etc.
- Station Disturbance Summary: Lists all disturbance details associated with the station being displayed.

Reporting Status:

- Reporting Status Summary: Summarizes all ATEC sectors and DSCS NCEs which have missed scheduled report times.
- Report Index: Allows retrieving any transmission system report submitted to ACOC for review.
- Report Detail: Actual ACOC report text.
- Report Disturbance Detail: Lists the overdue reports on a sector or NCE control area basis (see Figure 2-12).

Network Resources Status:

- Station Resource Summary: List of trunks terminating at a station and details per the "station file" data base entry (Report 2, Table 3-13).
- Link Detail: Source, destination, and other details per the "link file" data base entry (Report 2, Table 3-15).

- Trunk Detail: Source, destination, circuits carried, and other details per the "trunk file" data base entry (Report 2, Table 3-16).

- Circuit Detail: The source, destination, trunk list of the route, and other details per the "circuit file" data base entry (Report 2, Table 3-17).

- Fault Detail: Lists a transmission failure, service affected, and other details per the "fault file" data base entry (Report 2, Table 3-18).

- Multiplex Diagrams: A graphic display of groups forming a link between two stations.

Altroute Plan Status:

- Altroute Plan Summary: Display of an altroute patching plan for all stations involved in the altroute (see Figure 4-15).

- Altroute Plan Station Details: A subset of the plan summary dealing with a specific station's patching (see Figure 4-16).

- Normalization Plan Summary: Display of a normal route normalization patching plan for all stations involved (see Figure 4-21).

- Normalization Plan Station Details: A subset of the plan summary dealing only with a specific station's patching (see Figure 4-22).

2.4 CONTROL IMPLEMENTATION

2.4.1 Introduction

One transmission system control which has been assigned to ACOC is altroute generation for failed route conditions. Section 4 of this report discusses reasons for applying this control at ACOC. The main arguments in favor of altroute control at ACOC, rather than at sectors, were ease of maintaining data base consistency and computer availability. This section summarizes the altroute control algorithms and inter-site communications required to implement these controls. The companion control of route normalization is also addressed. The detail references for this discussion are Section 2 of Report 3 (altroute algorithms) and Section 4 of this report (implementation).

2.4.2 Altroute Control

2.4.2.1 Altroute Searching Algorithms--The main transmission control recommended is automated altroute generation. An automated tool for altroute generation will assist in the maintenance of effective critical restoral plans and the timely selection of new alternate routes should that become necessary. The inputs for the algorithms are the fault isolation reports of ATEC and the status messages from ATEC and DSCS/CS. The fault isolation and status reports initiate algorithm execution and allow the ACOC data base to stay current so that reliable altroutes are constructed.

The actual altrouting algorithm is a package of algorithms which support the altroute search routines (see Figure 2-13). ATEC and DSCS/CS fault isolation reports enter the main calling routines where a queue is maintained

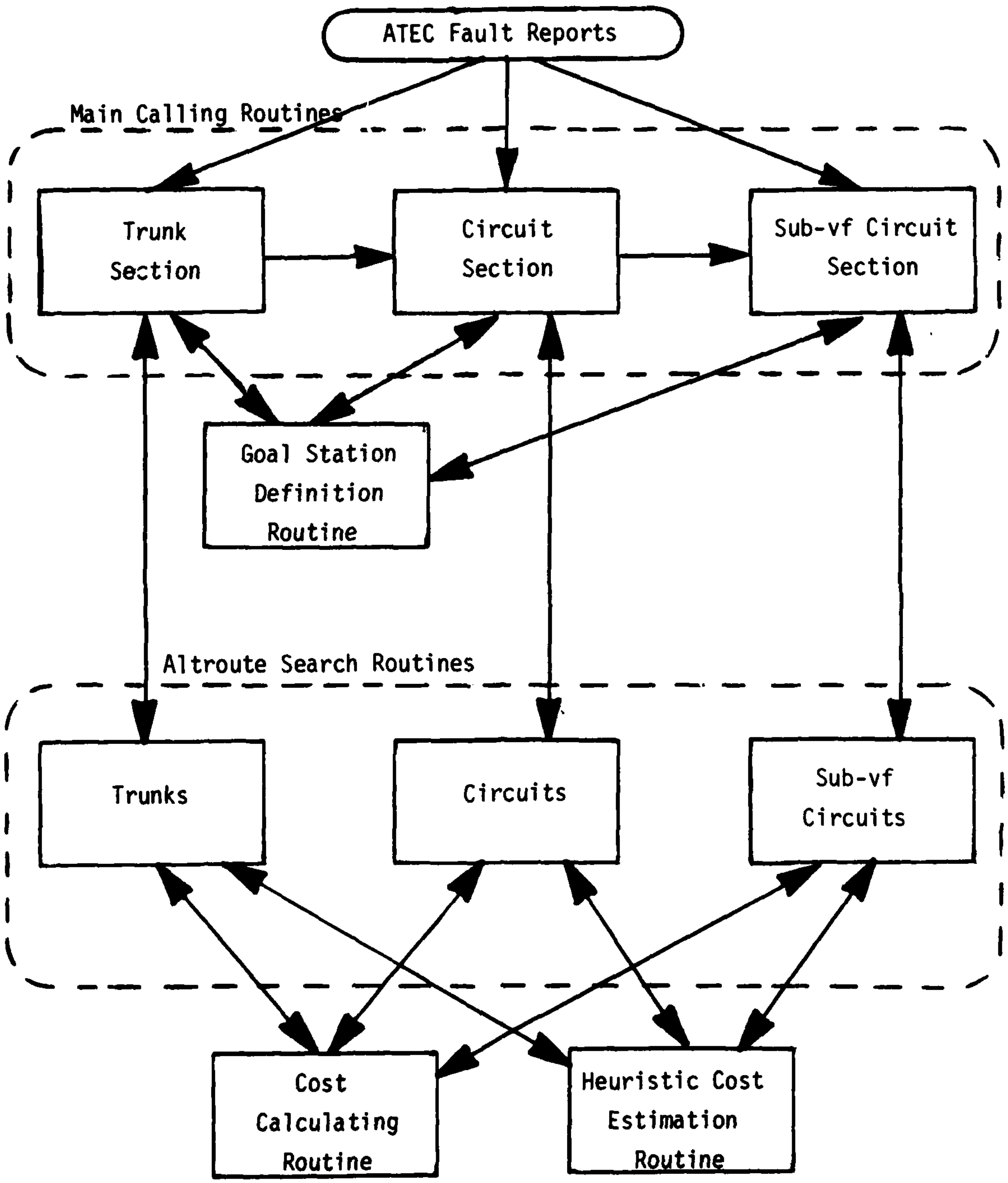


Figure 2-13. Altroute Algorithm Package

for the search routines so that the most crucial services receive priority attention. The definition of failed and intact segments from which the altroute must begin are also determined here in order to group jobs requiring similar altroutes. The goal station definition routines perform this segment definition as a service to the main calling routines. The next step is to begin work on the job queues that have been created. Trunks are altrouted first, then circuits, and finally sub-vf circuits. The order of this work schedule ensures that the largest number of users are handled first. The main calling routines call their corresponding altroute search routines to actually synthesize the altroutes. Those routines, in turn, make use of the cost calculating routine and heuristic cost estimation routine in order to select the most desirable routing. Failure to altroute at a given level (trunk, circuit) will result in decomposition of the service into its lower-level multiplex services and submission of those services for altrouting.

A key concept in the search algorithm is the node labelling process. A variation of this process is the basis of this or any other network search algorithm. Figure 2-14 shows the node labelling routine in flow chart form; however, the easiest way to understand the routine is through an example. Referring to Figure 2-15, we will use the algorithm of Figure 2-14 to find a minimum cost path from node S to node G in this simple network. The numbers alongside each link represent a "cost" of some sort which defines the desirability of using the link on the path to be found. The actual altroute search can assign costs for the DCS links to reflect desirability. The search begins by selecting the lowest cost node listed as OPEN. Nodes in list OPEN have been accessed already and added to a path, but they have not been examined for path expansion yet. The only node at this time is S. Nodes A, B, and D are found to be accessible from S. Each has a label

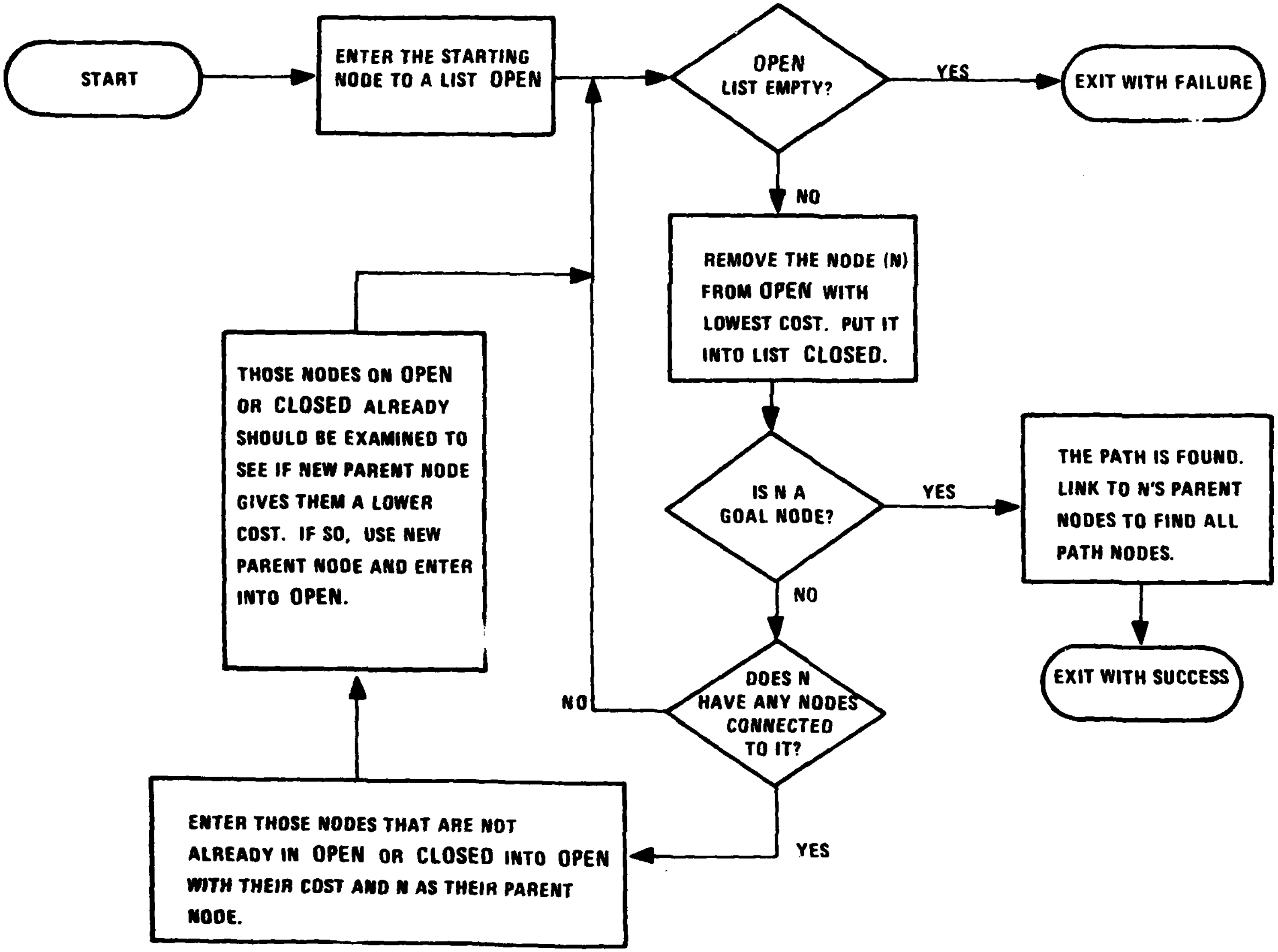


Figure 2-14. Node Labelling Routine

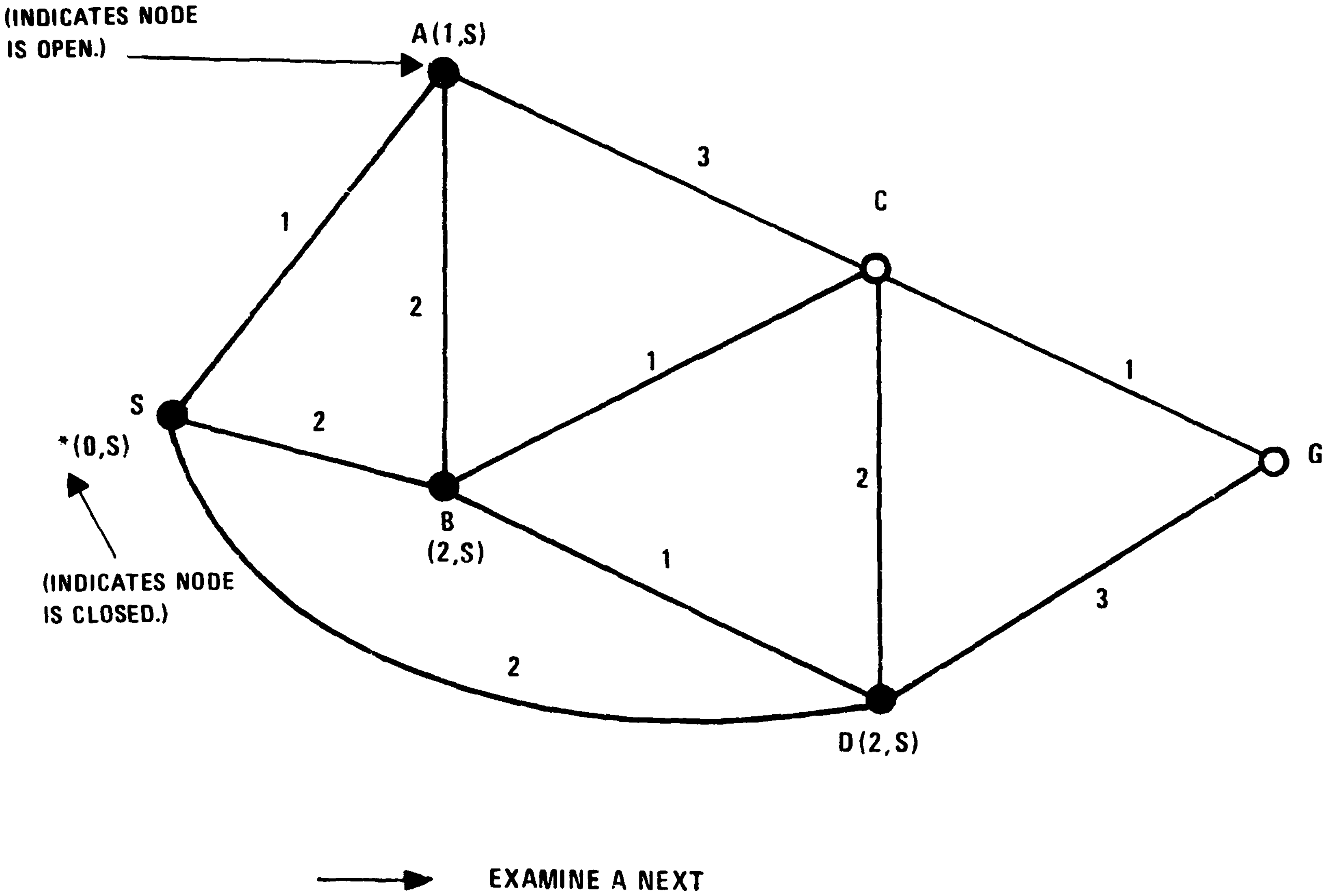


Figure 2-15. Step 1

assigned to it indicating the node used to access it (that is, its "parent station") and the cost of the path from S to the node. Once all accessible nodes are labelled, node S is labelled as CLOSED. Nodes in list CLOSED are nodes on a path and have been examined for path expansion already.

Examining all nodes labelled OPEN, we see that the next node for path expansion (due to its low "cost") is node A (see Figure 2-16).

The nodes accessible from A are S, C, and B. Labels are made for all nodes from A. Those labels which have a higher cost than that from the current label are not kept. Labels which supply a previously labelled node with a lower cost are kept and the previous labels discarded. The "parent station" string defines the path to any node. The label on C indicates the path to it came from A, and A's label indicates that S preceded it on the path through it.

The algorithm proceeds similarly from nodes B (Figure 2-17) and D (Figure 2-18). Because G was labelled from D does not mean the search is complete. The path from D has a cost of 5, while the lowest cost is 4 over a path from C. The search terminates when the goal node (G) is selected as the lowest cost node in OPEN. Using this type of termination guarantees that the lowest cost path is found. Figure 2-19 shows C labelling G with lower cost and thus setting up the discovery of G as the lowest cost OPEN node to expand. The path search ends and the path S to B to C to G with cost 4 is found as optimum.

Relating this to the DCS, the nodes are stations at which circuits and trunks can be patched. The links refer to trunks (for circuit altrouting) or links

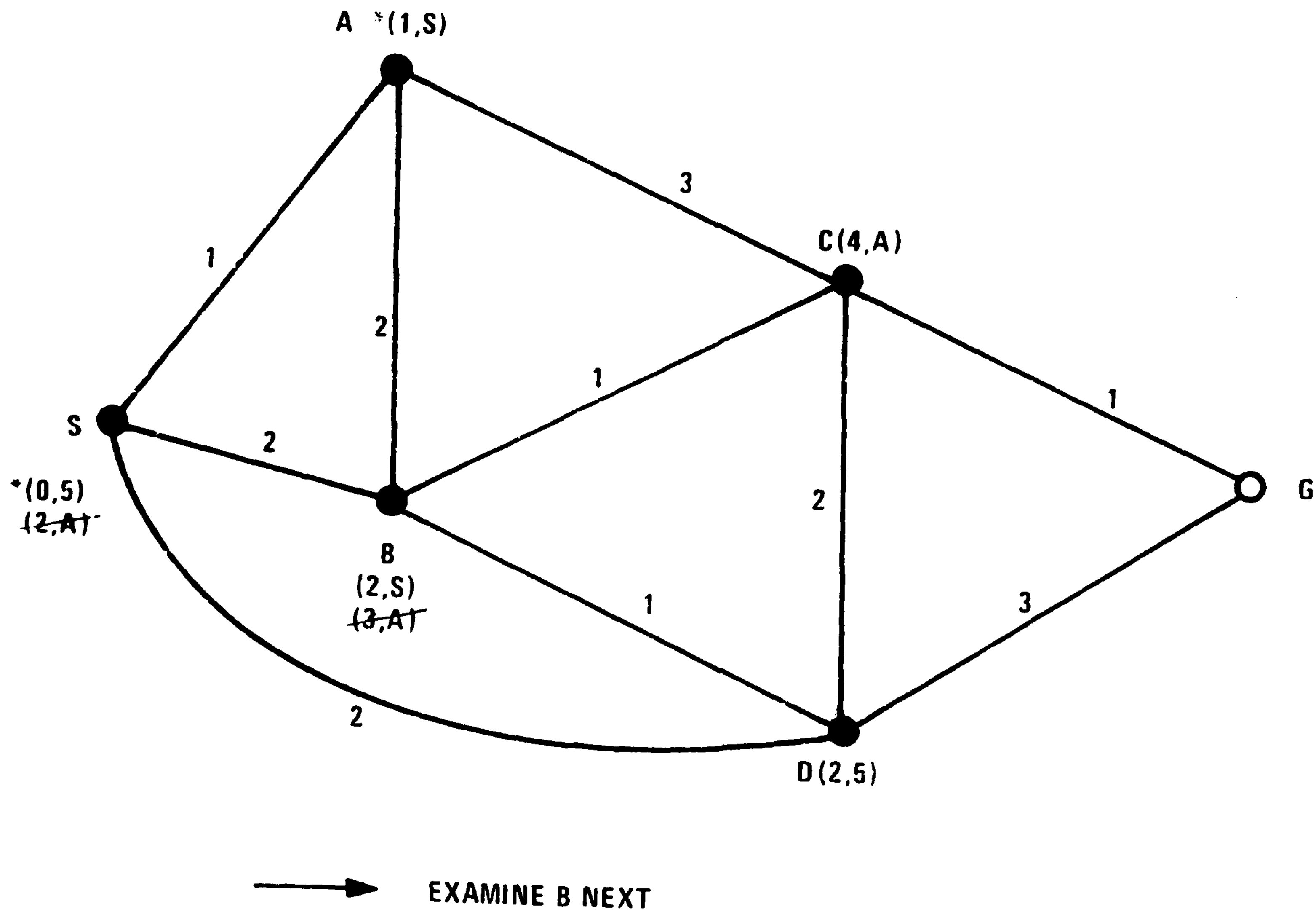


Figure 2-16. Step 2

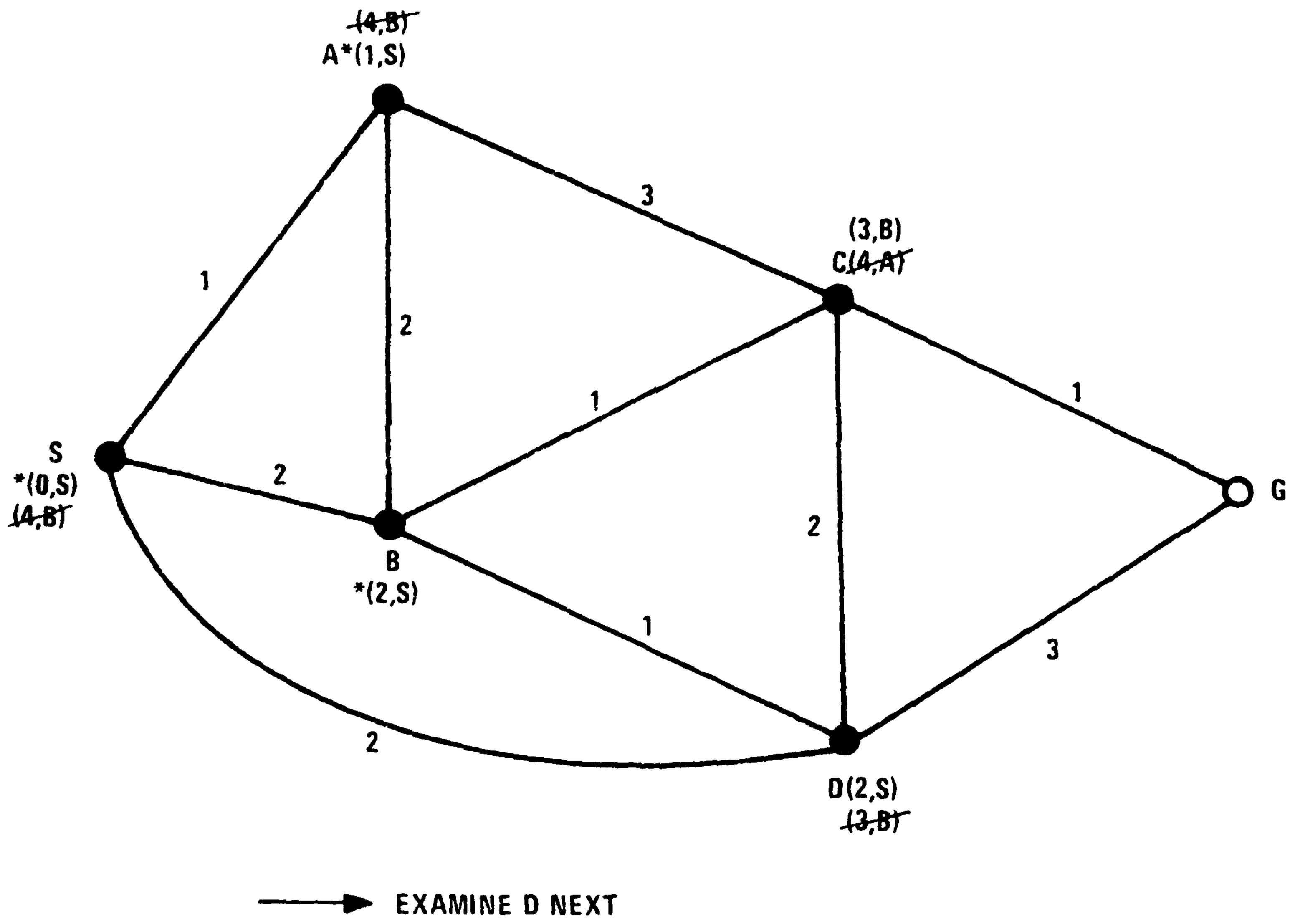


Figure 2-17. Step 3

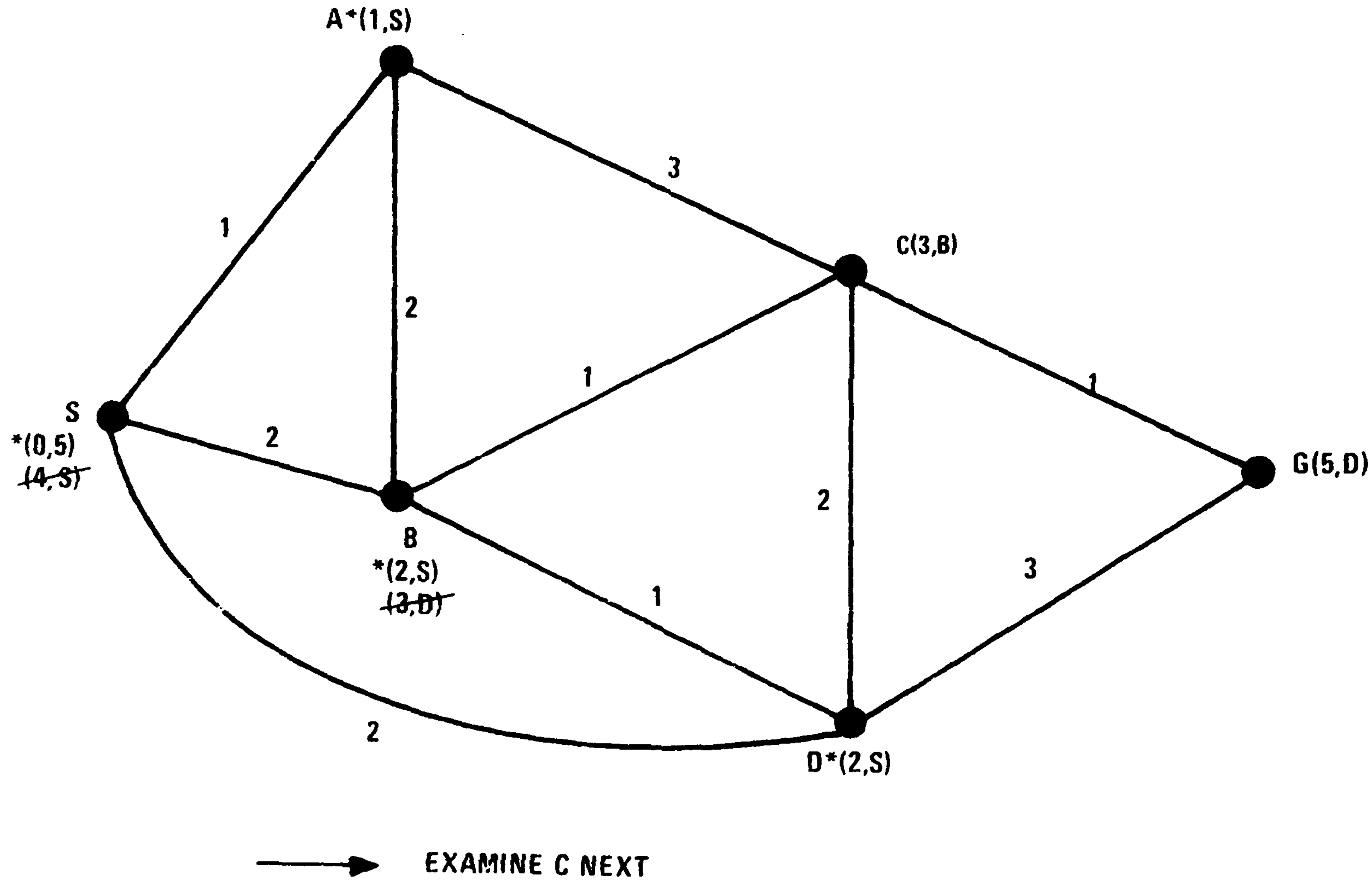
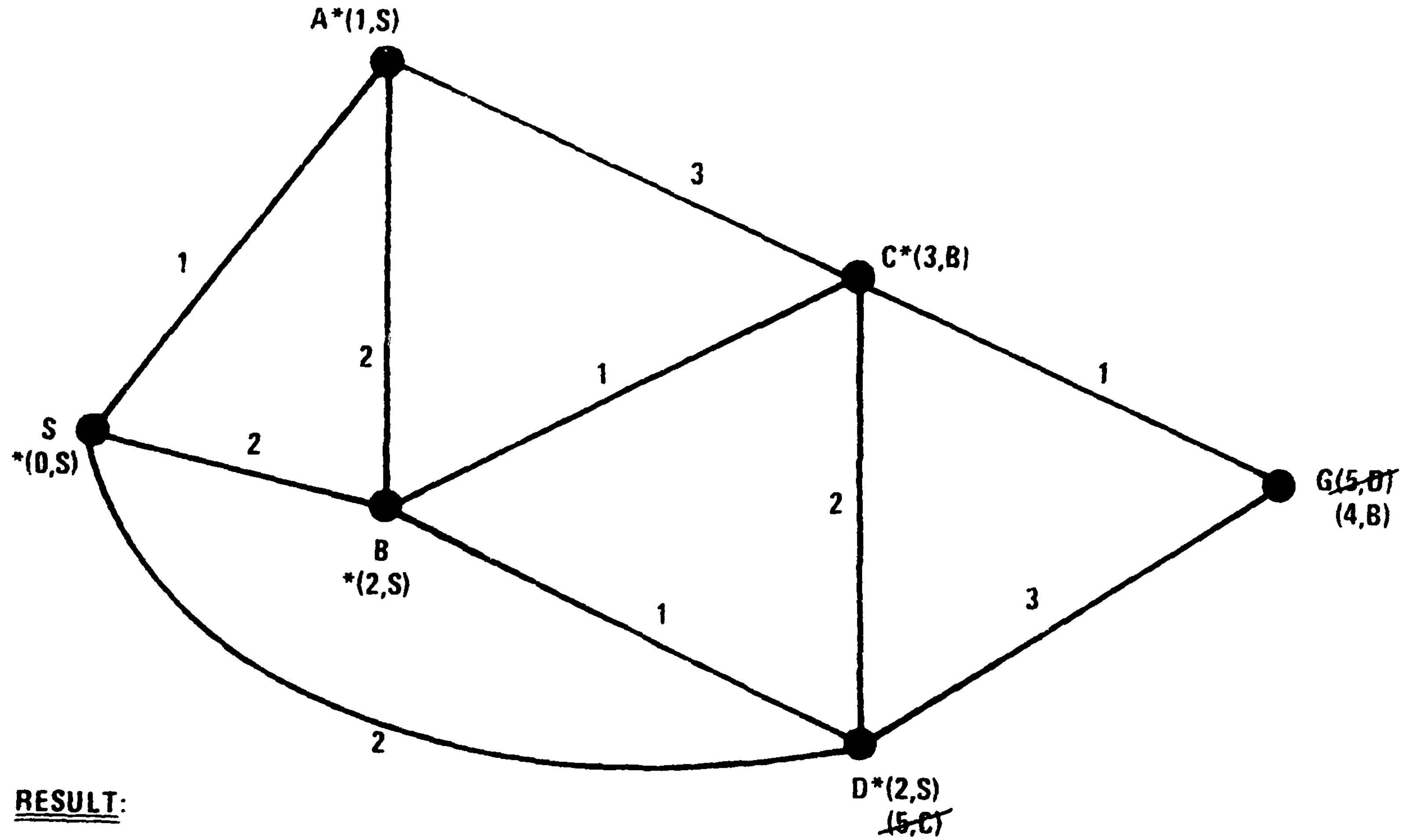


Figure 2-18. Step 4



RESULT:

PATH: S ⟶ B ⟶ C ⟶ G

COST = 4

Figure 2-19. Step 5

(for trunk altrouting). The search for stations accessible from an OPEN station is a search for spare or preemptable circuits or trunks which the altrouted circuits or trunks can use to that station.

The link costs for the altroute search algorithm reflect the desirability of the route and the preemption penalty paid for its use. Costs which are recommended for the search are:

- Mileage of the altroute over DCS transmission facilities
- Sum of the RPs of the circuits preempted in order to use the altroute
- Number of patching stations involved in creating the altroute
- Type and reliability of the links used in the altroute

The first and third items in the list are already route desirability considerations for DCS route planning. The other two are operational performance criteria used informally by tech controllers in selecting altroutes.

The variation of the node labelling routine that makes the altroute search effective and timely is the addition of heuristic cost estimates to the expansion of a path node. The labelling routine described in the example labelled nearly all nodes before terminating. The altroute search must label fewer nodes to be effective. The technique for accomplishing this is to estimate the cost of the altroute from the current search station to the goal station even though the path to the goal is not yet determined. This estimate can be made with heuristic knowledge of the problem, as Report 2 (Section 2.6.4) points out. The effect of adding this estimated cost to the actual cost is to avoid penalizing a path expansion from further consideration

just because it is longer than other paths. Since the sum of known and estimated costs at each OPEN node is the full path cost, short and long partial paths are weighted equally. Thus, the optimum path is found quickly without slowing the search with a large number of possibilities which will ultimately prove nonoptimum.

2.4.2.2 Altroute Implementation--The definition of altrouting control is not complete unless the inter-site communication for altroute implementation is defined. The previous section defined the algorithm support that altrouting control has at its disposal. The current section addresses how to make use of the algorithm results.

The summary of the activities that will take place between DCS operations sites during altrouting are given in Figure 4-5 of this report. Section 4.3.1 which accompanies that figure details the activities. The control flow begins with transmission system fault isolation reports. If the estimated time of repair (ETR) of the equipment permits, ACOC algorithms find an altroute. The altroute patching plan appears at the ACOC display simultaneous to the fault isolation report. This provides the controller with a solution to the problem causing the alert which may be immediately approved and implemented.

Once ACOC approval of the plan is obtained, patching messages are sent to involved stations via the ATEC message channels. The stations review the plan to determine if it coincides with the current status of equipment being used at their station. This step allows status updates that were erroneous to be corrected and allows late updates to be included in the plan.

Once all stations concur with the plan, ACOC sends the final instruction to all of them to implement. The data base links to the new altrouted are then made. Rejection of a plan at a station is accompanied by an exception report to enable ACOC control to modify the data base in order for a subsequent altroute search to succeed. The details of the displays for this are given in Figures 4-9 through 4-17 of this report.

2.4.3 Route Normalization

2.4.3.1 Normalization Algorithms--Once equipment repair has occurred, altrouted circuits or trunks must be routed back to their normal routes in order to remove preemptions that may have been made. The normalization routine described in Report 3 (Section 2.6.6) accomplishes this task.

The input to activate a route normalization is the repair of equipment on the normal route. The presence of this condition is sensed by the removal of the last fault file attached to a circuit or trunk in the data base (see Figure 2-6). An initial check is made to determine if the normal route contains any preemptions. Preemptions on the normal route cannot be removed because the preempting circuit or trunk must have had a higher RP to preempt in the first place. If this is the case, the normalization job is queued with other jobs until the preemptions are removed from its normal route. If the normalization can be made, the patching messages are assembled for normalization. The normalization may have removed preemptions from circuits or trunks waiting in the normalization queue. The job queue is checked for this condition, and normalization is carried out for circuits or trunks which are now free of all preemptions.

2.4.3.2 Implementation of Normalization--To complete the normalization control implementation, the inter-site communications to carry out the patching are defined. Figure 4-6 in this report summarizes the activity in flow chart form. Section 4.3.1 accompanying the figure details the procedure of the flow chart. The activity follows the altroute implementation almost exactly. The messages sent for patching are similar in order to minimize confusion. The station approval requirement of patching again verifies the timeliness of the ACOC data base.

2.5 SUMMARY OF TRANSMISSION CONTROL

This section has briefly reviewed the results of the transmission system control design of Reports 2 and 3 of this study. The four main areas of design (parameter collections, communications, analysis, and control implementation) have been addressed in order to demonstrate the feasibility of the design.

The results of this control design are:

- A data base design to support network connectivity
- Displays of data base files arranged to support key ACOC requests for information
- An altrouting package to aid in restoring service around failed transmission segments in order to improve service availability

SECTION 3

AUTOVON CONTROL

3.1 PARAMETER COLLECTION

The portion of this study in reference 2 was based on AUTOSEVOCOM II using the AN/TTC-39 and SB-3865 switches. The details of the parameter selection and collection methodologies contained therein are not applicable to the 490L network. However, the general approach to parameter selection is independent of the details of the switching hardware employed. Since AUTOSEVOCOM II was cancelled, this analysis has been revised to reflect the requirements of 490L AUTOVON.

Circuit switched network parameters basically fall into two classes as follows:

- Traffic parameters
- Equipment status parameters

These types of parameters are not independent of each other as changes in equipment status modify observed traffic parameters. There are parameters which do not neatly fit in either class such as trunk timeouts. However, for the purposes of exposition, it is useful to make this breakdown.

Traffic parameters measure the demand for service in the network and are typically counts of events or measures of average utilization of network equipment. Although the status of network equipment could be deduced from

them, we recommend against this use of traffic parameters for the following reasons:

- All forms of equipment status changes can either be alarmed on occurrence or can be monitored by scanning at frequent intervals.
- Traffic parameters, being driven by a stochastic process, require extensive smoothing before being applied to an alarm threshold.
- Network equipment status changes have complex, nonlinear interactions with traffic parameters throughout the network.
- It would be very difficult to separate traffic parameter changes due to network status changes from those due to traffic level changes.

Therefore, traffic parameters are recommended for determining the network traffic level. Since the history of the actual traffic level is completely independent of the future traffic level, there is also no way that traffic parameters could be used to predict or trend traffic levels. Traffic level predictions can only be made based on daily, weekly, and seasonal business cycles and other external information such as defense condition (DEFCON).

3.1.1 Traffic Parameters

The traffic parameter selection matrix for the AUTOVON switch is shown in Table 3-1. They are based on the analysis contained in the following paragraphs.

TABLE 3-1. TRAFFIC PARAMETER SELECTION MATRIX

Parameters	Sampling Interval (Min)	Real-Time Use	Long-Term Engineering Use
Node Parameters			
Local calls offered	60		X
Call originations	60		X
Calls terminated	60		X
Tandem calls	60		X
Calls blocked, by precedence	10		X
Calls with dial tone, delay 1 second	10		X
Calls complete, by node	60		X
Trunk Parameters			
Calls offered, total	10	X	X
Calls offered, by precedence	10		X
Calls blocked, no idle trunk	10	X	X
Calls blocked, no common equipment	10		X
Calls incoming	10		
Calls preempted, by precedence	10		X
Preempts blocked, by precedence	10		X
Average number of trunks busy	10		X
Time congestion	5	X	
Trunk timeout	On Occurrence	X	

There are three types of traffic parameters as follows:

- Node parameters
- Trunk group parameters
- Source-destination pair parameters

Node parameters give information about the traffic at the switch making the report. Typical node parameters are the following:

- Local calls offered
- Call originations offered
- Call terminated
- Tandem calls
- Calls blocked, reported by precedence
- Calls with dial tone delay greater than one second

Node parameters do not provide enough detail for real-time system level control since they either report on strictly local problems or are too summarized to provide a clear picture. Local calls offered does not provide any information about network operations. If too many calls have delayed dial tone, the local switch controller should apply traffic load control to reduce the demand. Both parameters relate to strictly local phenomena. The remaining parameters summarize the traffic at the switch and could indicate an overall switch overload. They provide no detail about the characteristics of the overload which is needed to isolate the stress. This detail is provided by the trunk group parameters.

The direct indicator of processing load is another type of node parameter. On a stored program controlled switch, the percentage processor utilization can be directly measured and is an excellent indicator. With common channel signalling, queue sizes can be directly measured and used as a switch congestion indicator. For the 490L switch, the parameters are the following:

- Multiple frequency (MF) tranceivers busy
- Dual tone multiple frequency (DTMF) receivers busy
- Register sender junctors (RSJs) busy

If either the MFTs or the RSJs are all busy, the switch starts queuing tandem calls for call processing. If DTMF receivers are busy, local dial tone will be delayed. Queuing of tandem calls causes increased use of interswitch trunks for signalling purposes. If this becomes critical, trunk timeouts will occur; and the network may go into a thrashing state (defined as a condition in which increased offered traffic results in decreased carried traffic). The MFT and RSJ busy parameters must therefore be processed to identify switch overload.

The parameters which could be collected for each trunk group include the following counts of events:

- Calls offered, total and itemized by precedence
- Calls blocked due to lack of idle trunks
- Calls incoming on the trunk group
- Calls preempted, by precedence
- Preempts refused, by precedence

- Trunk utilization
- Time congestion
- Trunk timeout

Calls offered (attempts) is the basic traffic parameter. It is a direct count of every attempt to use the trunk group. By assuming an average time which any call would use the trunk, calls blocked and preempted can be estimated via the Erlang formulas. Call attempts are not measured by AUTOVON centralized alarm system (ACAS) sensors. They are measured by traffic data collection system (TDCS), but this equipment is questionable as discussed in Section 4.2.2.1. A parameter which is statistically equivalent for Poisson traffic, time congestion, is sensed by ACAS. Thus, for basic real-time control attempts are not required. For long term engineering or more precise distribution free control, attempts should be measured.

Calls blocked due to the lack of idle trunks (overflows) is the next most direct traffic parameter. Using this count along with the number of calls offered provides an estimate of trunk group performance which does not depend on assumptions about the hold times or the statistical distribution of attempts. There are disadvantages to using this parameter, as follows:

- Poisson statistics, using a historically derived hold time, predict network performance fairly well. This is especially true in a network like AUTOVON where trunk groups are not used as strictly high usage or final trunk groups but have some of each kind of traffic.

- Overflows are noisier than attempts, that is, they come less frequently and tend to come in bursts so a performance estimate based on overflows would need more smoothing than one based on attempts.

It would be useful to filter and threshold the ratio of overflows to attempts as a backup to thresholding just attempts in case the average hold time changes drastically, due to military conditions for example. It must be recognized that the observed call blocking ratio will be slower to respond when appropriately filtered than the attempts parameter. As with attempts, overflows are not measured by ACAS.

Calls incoming on the trunk group is a redundant parameter which is not useful if the control point has visibility of both ends of the trunk. It is just attempts minus overflows from the other end. This parameter would be useful if some sort of distributed control scheme was contemplated, but it has no place in the DCS hierarchical control structure.

Calls preempted and preempts refused are indicators of the basic traffic level, but they are very noisy parameters and hence not useful for real-time system control. They are noisy in the sense that a preempt attempt is generated only if all alternate routes overflow on an idle search. Each time an overflow process occurs, it has a larger ratio of variance to mean than the arrival process which generated it. Since a preempt is an overflow

of the final trunk group, preempts have a very large variance to mean ratio. In addition to being noisy, preemption counts still contain only basic traffic intensity data the same as idle attempts. Therefore, these parameters are not useful for real-time system control. They are useful for long-term engineering studies to determine if the precedence system is operating properly. In some network designs, preemption algorithms transfer precedence ratings between calls in an erroneous manner. This could be detected by long-term analysis of preemption count data.

Trunk group utilization is obtained by scanning the trunk group every few seconds and counting the number of busy trunks. The scan data is then averaged over the measurement interval of several minutes. For example, reasonable measurement rates would be every 30 seconds averaged over 15-30 minutes. Trunk utilization provides another good estimator of traffic intensity and is a valid alternative to measuring attempts. Combined with measurements of attempts and overflows, it removes distribution dependent assumptions in the measurement and can provide good information on what the actual arrival distribution is. It is therefore a very useful parameter for long-term engineering of the network. Time congestion is another equivalent measure of traffic intensity. It is measured by computing the portion of a measurement interval during which all trunks are in use. Time congestion is the traffic parameter actually measured by the ACAS system. Since time congestion is statistically equivalent to attempts or utilization, it is a sufficient measure of traffic intensity and is the only parameter required for real-time control.

Trunk timeouts are counts of calls which never receive a start signal from the distant end switch. This parameter is useful in two ways. If the number of timeouts is about equal to the number of attempts, the trunk has apparently failed. If the number of timeouts is much smaller than the number of attempts, but greater than zero, it is an indicator of critical congestion at the distant end switch. Upon confirmation of critical congestion, control actions would be taken to relieve the switch. This parameter exists only for trunks using in-band signalling.

Source-destination pair parameters relate to user-user traffic handling. The same basic kinds of parameters as for trunks exist, calls attempted, completed, preempted, etc. These parameters are all very interesting for long-term engineering. In the Bell system, these parameters are used to modify routing rules. In AUTOVON, the traffic patterns are too simple and the network too small to require the use of these parameters for real-time control.

Smoothing of Traffic Parameters--Traffic parameters are random variables and therefore typically have to be smoothed to be useful. The smoothing required is very much a function of the exact use of the parameter and some arbitrary decision criterion. In the case of system control, the expected use of the smoothed parameter is to make a decision whether the observed parameter came from a stressed traffic situation or from a normal unstressed traffic situation. This decision is made by placing a threshold on the smoothed parameter value.

Reference 2 contains a discussion of smoothing criteria. In general, smoothing time requirements have the following characteristics:

- Required smoothing decreases with larger trunk groups.
- Required smoothing decreases with heavier traffic.
- Required smoothing increases with the peakedness of the traffic.
- Smoothing time is more sensitive to nominal GOS than it is to the number of trunks in the group or the peakedness of the traffic.

For detecting overloads on trunk groups typical of AUTOVON, smoothing times on the order of 30 minutes are required.

Relation of Traffic Parameters to Network Status Parameters--The use postulated for traffic parameters is to detect changes in network traffic loads. For any given trunk group, the change can be caused either by a change in the basic demand for service or by a change in the network status. If the traffic level change is due to a change in network status, it would have been predictable based on network status parameters. No further information is obtained by observing that the traffic levels respond to the new network status.

If the traffic alarm thresholds are not changed and the demand for service as well as the network status changes, there is no way to separate an alarm due to network status from an alarm due to traffic. Therefore, whenever the network status changes, the alarm thresholds for traffic monitoring should be modified so that they still relate to changes in the demand for service; that is, they discount changes due to a changed network.

This modification of the threshold values can be accomplished by using a steady state model of the network to determine new nominal traffic values. Threshold offsets of some percentage can be applied to these traffic values. These expected traffic values and the resulting performance figures can be presented to the controller as further detail into what the status change means relative to network performance.

3.1.2 Equipment Status Parameters

Equipment status information must be accurate, timely, unambiguous and comprehensive in order to effectively control the network. Equipment failures can cause distortion of the traffic flow misleading the controllers as to the cause of the network stress. Further, if equipment failures are known, the remaining network can be reconfigured to maximize its utilization. For these reasons, DCAC 310-55-1 (Reference 5) specifies that any significant AUTOVON equipment failure should be immediately reported to ACOC.

Table 3-2 lists the equipment parameters required for AUTOVON. For each parameter the on-line unit, number of units failed, and number of units operational should be sent to ACOC upon the occurrance of a change of state. This differs from the current ACAS procedure which purports to show the equipment out of service. ACAS provides only a one or more failed indication of multiple frequency transceiver (MFT), RSJ and DTMF equipments. In the case of the marker, it indicates failure if the marker fails to complete its cycle successfully, resulting in a marker switchover. Since one marker is always on line, the ACAS display always indicates one marker operational. The parameter sensor should indicate marker failure when initial switchover

TABLE 3-2. 490L SWITCH STATUS ITEMS

Item	Unit Online	Units Failed	Units Operational	Manual Make Busy
Logic A, B	X	X	X	
Comparator Logic	X	X		
DTMF	X	X	X	X
RSJ	X	X	X	X
MFT	X	X	X	X
Memory X, Y	X	X	X	
Switch Marker A, B	X	X	X	
DSA Marker A, B	X	X	X	
Power Group	X	X	X	
Environment Monitor	X	X	X	
Maintenance Monitor	X	X		
DC-AC Inverter	X	X		
Trunk Scanner	X	X		
Clock	X	X		
Trunk Group	X	X	X	X

occurs, but it should continue to indicate failure if the marker comes back on line until a cycle is successfully completed.

In addition to basic event parameters, ACOC needs to be informed if any local controls are taken which impact network operations. These informal parameters are the following:

- Line load control applications
- Routing table change
- Translation table change
- Zone restriction change
- Trunk directionalization
- Manual make busy of common equipment or trunks

3.2 PARAMETER COMMUNICATION

As discussed in Section 4, the collection point for all AUTOVON parameters at the switch site is the RAMM. These parameters all go to the ACOC AUTOVON control data base. In reference 2 it was shown that the communication needline for periodic reporting from the TTC-39 switch, as used for a replacement AUTOVON switch, is less than 10 BPS.

Another estimate can be obtained by examining the TDCS data flow. For a switch with 10 trunks and 10 destinations, TDCS counts 482 items. The item with the largest count is the total attempts at the switch. The busiest switch has a traffic load of under 50E, so certainly less than 50 attempts/ minute are made. Thus, the maximum value of an hourly count is 300, and

a 3-digit count field is sufficient. At 10 bits/character, the total data rate is 4 BPS. Allowing 100% overhead for message formatting and error checking, a transmission rate of 8 BPS is obtained. Therefore, the 10 BPS needline is a reasonable estimate for periodic traffic reporting on switches the size of European AUTOVON.

Reporting of equipment status does not need to be done on a periodic basis, but rather only when a change in status occurs. With this type of reporting system, the communications path must be sized according to the worst case delay which is tolerable. In reference 2, a 120 BPS requirement was determined for the TTC-39 switch. This requirement is also reasonable for the 490L/RAMM system.

There are basically four logical candidates for telemetry of AUTOVON data:

- A dialup system currently used to TDCS
- ACAS telemetry circuits
- ATEC via a CIS port
- ATEC via a NCS system control (SYSCON) port

The dialup system used by TDCS is a 1200 baud system and therefore has sufficient capacity. However, it uses the reported on switch as a part of its reporting path and is therefore unavailable when needed most. ACAS has dedicated 75 baud telemetry circuits. These circuits would have to be upgraded to handle the 120 BPS requirement. They also are half duplex reporting to, not accepting commands from, ACOC. It is further an inefficient use of resources to dedicate 120 BPS circuits all across Europe

to handle a 10 BPS average requirement. Thus ATEC, with its message switching telemetry structure, is a highly attractive candidate for telemetering AUTOVON data.

ATEC could either be entered on a 150 baud CIS port, looking just like another MAS element, or it could enter the node directly into one of the specified spare 2400 baud circuits. Since AUTOVON switches are located at the larger DCS stations, it is possible that the CIS ports are fully occupied. This is especially true if all the other CIS interfaces recommended here are implemented. There is a NCS colocated with each AUTOVON switch with an unused 2400 baud port, and the RAMM can control a 2400 baud interface as easily as a 50 baud interface. For these reasons, it is recommended that AUTOVON switches report via the NCS 2400 baud port. NCS and SCS still have no AUTOVON function except to transfer messages to and from ACOC.

3.3 PARAMETER PROCESSING

The parameters are used at the ACOC for the following functions:

- Provide the controller with accurate real-time status of the network
- Alert the controller of status changes requiring attention
- Make automatic decisions regarding changes in routing procedures

In support of the first function, parameter reports are sorted into an AUTOVON data base. This data base contains all the information about the

network's configuration and status necessary to perform real-time theatre level AUTOVON control functions. The data is contained in the following seven file types:

- Network configuration file
- Switch equipment status and history file
- Switch configuration file
- Switch traffic file
- Trunk group status file
- Trunk group traffic file
- Critical user access status file

The interrelationship of these files is shown in Figure 3-1. The content of the files is shown in Table 3-3 through 3-9. For a network the size of European AUTOVON, the total size of this data base is about 32,000 bytes.

In support of the first function, a set of displays has also been defined. These displays and the overall display concept is patterned after the AUTODIN II concept. Controllers may cross-train and work both networks. By using a similar display concept, this process is expedited. Also, the AUTODIN II display concept is a modern, well thought out system of displays.

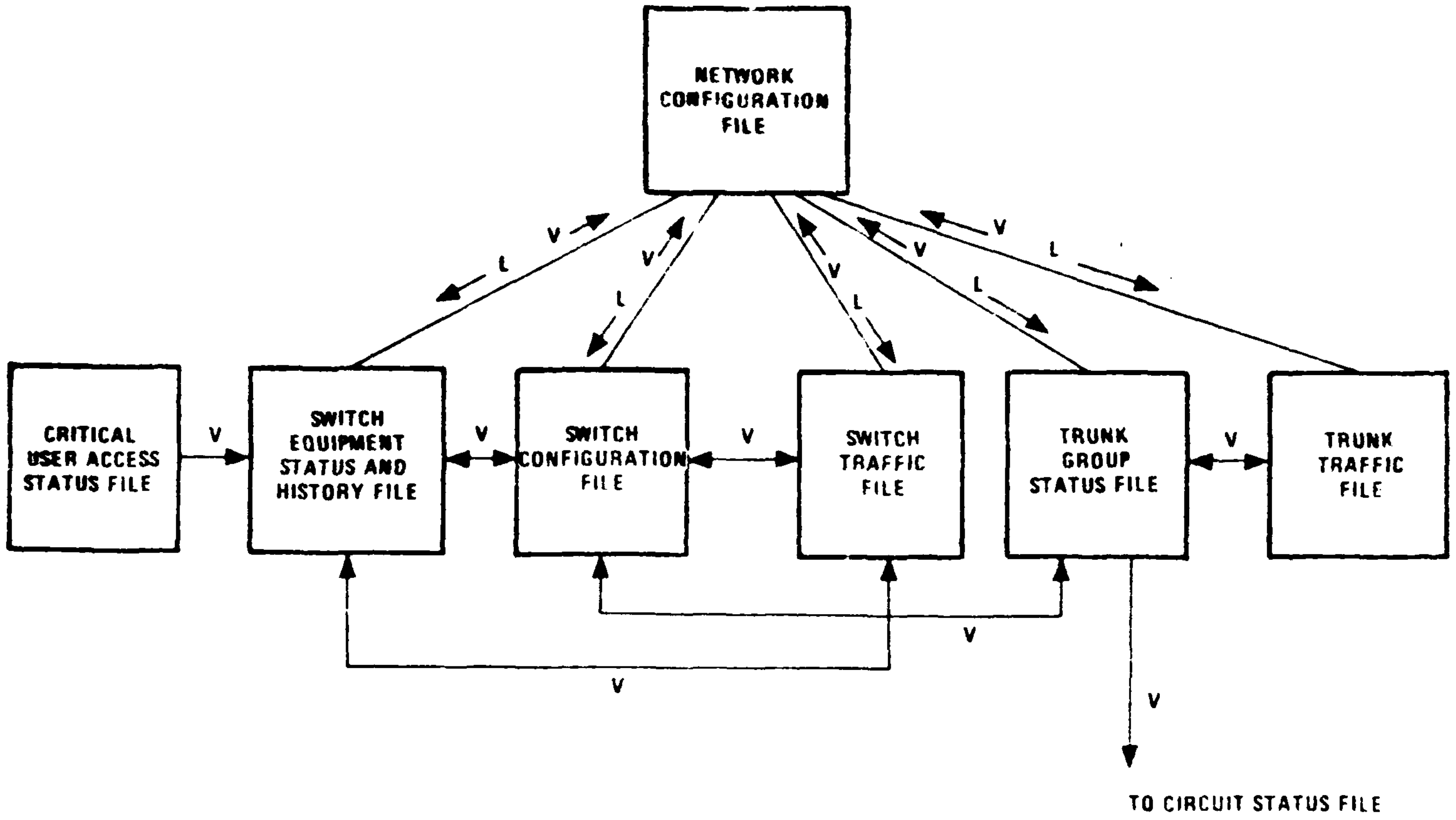


Figure 3-1. AUTOVON Data Base

TABLE 3-3. NETWORK CONFIGURATION FILE

Item	Comments	Size (Bytes)
Switch names	Provides correspondence between DCS station name and network logical switch number. Three (3) ASCII characters per switch.	27
Connectivity table	Provides forward pointer from network connectivity to logical trunk group names. Two (2) BCD digits for each end of each trunk group, indicating terminating switch.	50
	TOTAL	77

Number of such records--1

Total bytes--77

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SYSTEM CONTROL FOR THE TRANSITIONAL DCS.(U)
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TABLE 3-4. SWITCH EQUIPMENT STATUS AND HISTORY FILE

Status and history subrecord for each reportable piece of equipment listed in table, containing the following:

Item	Comments	Size (Bytes)
Number operating	Provides indication of operating resource.	1
Number standby	Provides indication of reserve resource.	1
Number failed	Provides indication of currently inoperable resource.	1
Failure rate	Total number of failures/total operating time required by 310-130-2.	4
Average restoral time	Used by controller to determine whether or not a response to a stress is appropriate.	1
Average repair time	Same as restoral.	1
Number of accumulated failures; daily, monthly, yearly	Used by controller to be aware of abnormal failure problems. Provides controller with insight as to what may be expected to fail, so that he does not place excessive demands on weak equipment.	3
Failure time integral	Total time a piece of equipment has been in a failed state; provides measure of equipment availability.	6
	TOTAL	18

Number of records per switch--15

Total records--150

Total bytes--2700

TABLE 3-5. SWITCH CONFIGURATION FILE

Item	Comments	Bytes
Routing table	Expanded to support adaptive routing. Includes for each destination switch the switch number (2 binary coded decimal, digits), each segment of a route to that destination for each trunk group exiting this switch, and its status (50 bytes).	510
Trunk groups in operation	Number of each trunk group terminating on this switch.	20
Code translation tables	Contains station and line code translations used for inter-networking and ring-around-the-rosey prevention.	100
	TOTAL	630

Number of such records--10

Total bytes--6300

TABLE 3-6. SWITCH TRAFFIC FILE

Item	Comments	Size (Bytes)
Automatic traffic overload protection (ATOP) line load control status		1
Calls blocked by precedence	Last hours total	5
Dial tone delay (1 second)	Last hours total	1
Total switch accesses	Last hours total	4
Calls completed	Last hours value for each node	20
	TOTAL	31

Number of such records--10

Total bytes--310

TABLE 3-7. TRUNK GROUP STATUS FILE

Item	Comments	Size (Bytes)
Trunk group ID	Logical. A number from 1-127 used by the TTC-39 to identify the group.	1
Command circuit service designator (CCSD) for each trunk (last 4 characters)	Each trunk is a separately identifiable circuit at the transmission system interface. There could be up to 50 trunks in a trunk group, each with its own 4-character CCSD.	200
Transmission status	For each circuit, 1 byte to indicate status as seen by the switch network and as seen by the transmission system.	51
Analog signalling status	Indicator of signalling type: MF confirmation, nonconfirmation, etc.	1
Failure reports	Last 20 reports (1 CRT screen full) or 24 hours, whichever is less. Informs controller of recent history of trunk group.	440
	TOTAL	693

Number of such records--25

Total bytes--17,325

TABLE 3-8. TRUNK TRAFFIC FILE

Item	Comments	Size (Bytes)
Current readings of all traffic parameters	Details used to solve unusual traffic problems.	48
Filtered values--measured call congestion, offered traffic	Primary parameter for alarming traffic overload.	2
Alarm and warning level thresholds	Values for call congestion and offered traffic which initiate alarms.	4
Hourly values of call congestions	Used by controller to identify demand trends past 24 hourly values.	24
	TOTAL	78

Number of such records--25

Total bytes--25 x 78 = 1550

TABLE 3-9. CRITICAL USER ACCESS STATUS FILE

Item	Comments	Size (Bytes)
Loop ID	Switch number and physical loop number (BCD).	6
Loop circuit CCSD		8
Telephone number		3
Location	Physical location of subscriber.	10
Access status	Operational/non-operational condition of access circuit, terminal equipment.	$\frac{1}{2}$
Security requirement	Access circuit security requirements needed for rehoming.	$\frac{1}{2}$
Subscriber instrument type	TA 341, WECO 500D, etc., needed for rehoming.	1
Signalling classification	Dial pulse, DTMF, etc., needed for rehoming.	1
	TOTAL	30

Number of such records--50

Total bytes--1500

The AUTOVON displays are divided into five major classes, as shown on the display hierarchy chart (Figure 3-2). The major categories of displays are as follows:

- Traffic displays
- Switch equipment displays
- Trunk equipment displays
- User access circuit and equipment displays
- Text and general information displays

The information is arranged hierarchically, with a summary display of everything in the network (Figure 3-3) available at the top of the hierarchy. Displays of progressively greater detail are provided at lower levels of the hierarchy. Figures 3-3 through 3-10 show the format of these displays.

The routing table display, Figure 3-10, is particularly important because it supports manual control of the routing. When this display is active, the controller can directly interact with the processor to modify switch routing tables or the manner in which the tables are automatically revised. There is one display for each switch in the network, and it displays the currently active routing to each destination switch. The character following the route indicator shows whether the routing is being automatically controlled (blank) or manually forced (*), if the route is a spill route ($), and if the route is currently carrying only primary routed traffic (!). If a switch has been destination code cancelled, destination code cancellation (DCC) appears as its primary route; and the remaining routes are filled with asterisks. The controller can modify the switch routing by moving the cursor to a

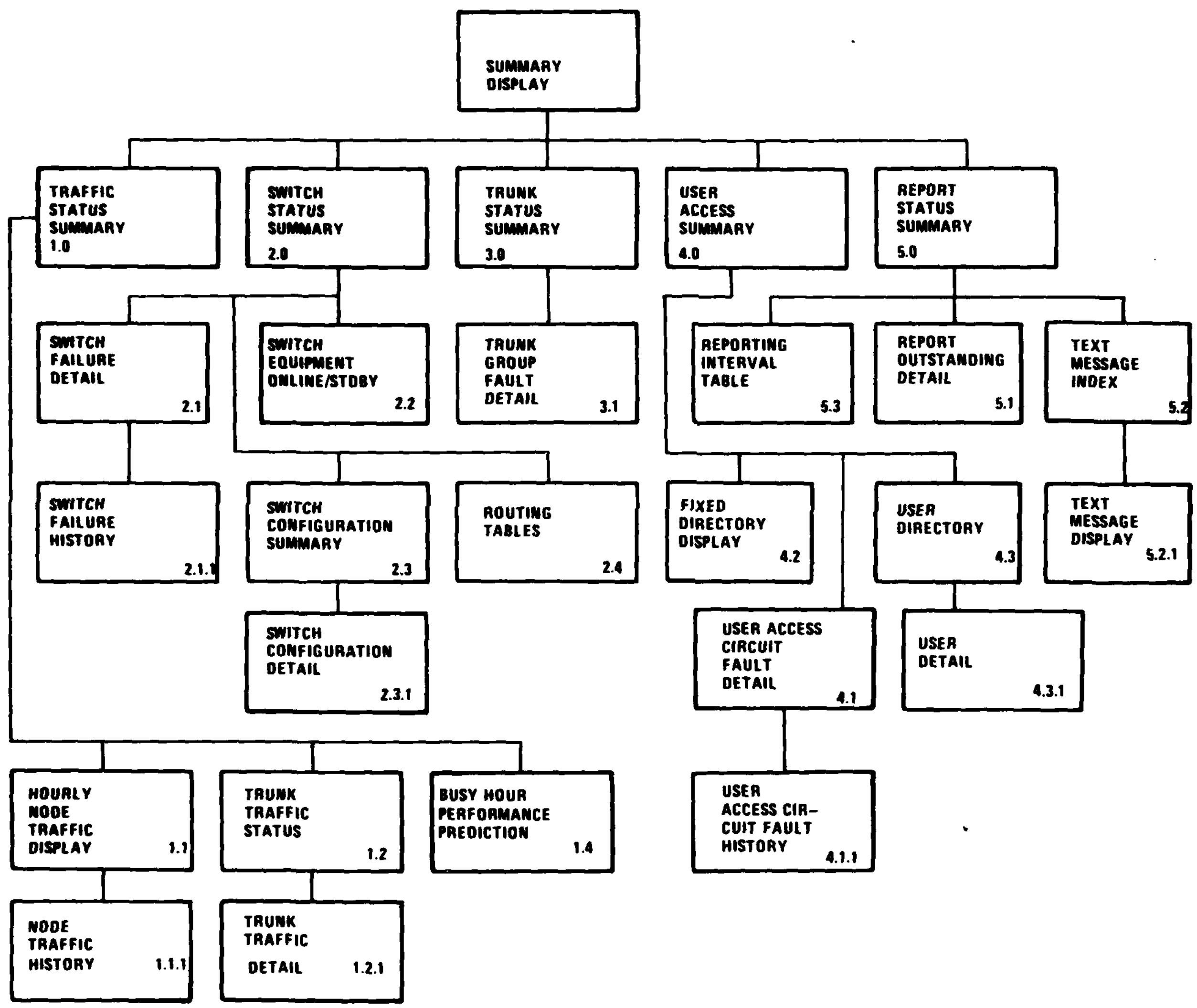


Figure 3-2. AUTOVON Display Hierarchy

	HIN	MAM	SCH	FEL	DON	LKF	CTO	MRE	HUM
TRAFFIC	+	+	+	+	+	+	ALARM	+	+
SWITCH EQUIPMENT	+	HAZ	+	+	+	+	+	+	+
TRUNKS	+	+	+	+	+	+	+	+	+
USER ACCESS	+	+	+	ALARM	+	+	+	+	+
MESSAGES	+	+	+	0•DUE	+	+	+	+	+

Figure 3-3. Network Status Summary Display

	HIN	MAM	SCH	FEL	DON	LKF	CTO	MRE	HUM
PRIORITY CALLS	+	+	+	+	+	+	ALARM	+	+
DIAL TONE DELAY	+	WARN	+	+	+	+	+	+	+
TRUNK BLOCKING	+	+	+	+	+	+	+	+	+
COMMON EQUIPMENT BLOCKING	+	+	+	9	+	+	+	+	+
PROCESSOR LOAD	+	+	+	WARN	+	+	+	+	+

Figure 3-4. Network Performance Summary Display

	HIN	MAM	SCH	FEL	DON	LKF	CTO	MRE	HUM
LOCAL	82	250	78	160	124	136	44	80	148
ORIGINATING	404	322	192	685	658	724	252	259	326
TERMINATING	305	287	222	734	906	700	098	220	294
TANDEM	1720	55	2	1580	504	74	5	945	

Figure 3-5. Hourly Node Traffic Summary Display

	HIGH PRIORITY				*	TOTAL			
	GOS	ATB	OFFRD	UTIL		GOS	ATB	OFFRD	UTIL
HIN-FEL	000	000	7	.070		086	21	238	.728
HIN-MAM	000	000	6	.140		000	0	251	.371
HIN-LKF	000	000	3	.073		017	3	154	.546
HIN-DON	000	000	10	.071		502	165	328	.831
HIN-HUM	000	000	2	.200		043	6	129	.593
MAM-FEL	000	000	4	.100		011	2	137	.465
MAM-DON	000	000	16	.077		304	129	424	.861
SCH-FEL	000	000	4	.077		009	1	132	.506
SCH-DON	000	000	6	.083		063	12	183	.669
SCH-LKF	000	000	5	.125		075	8	99	.569
FEL-MRE	000	000	0	.050		081	3	37	.781
FEL-DON	000	000	27	.077		191	157	820	.895
FEL-LKF	000	000	19	.077		100	64	622	.835
FEL-CTO	000	000	5	.091		059	9	156	.627
DON-MRE	000	000	4	.071		046	10	209	.663

Figure 3-6. Trunk Traffic Status Display

	FLASH OV	FLASH	IMMEDIATE	PRIORITY	ROUTINE
GOS	000	000	000	000	000
OFFERED	2	5	127	59	45
NO IDLE TRUNK	000	000	28	14	11
NO COMMON EQUIP	000	000	000	000	000
PREEMPTIONS	000	1	28	14	11
PREEMPTIONS BLOCKED	000	000	3	7	11

Figure 3-7. Trunk Traffic Detail Display

	CDB	POT	HIN	MAM	SCH	FEL	DON	LKF	CTO	MRE	HUM
CDB	\		.48	.48	.48	.48	.50	.49	.49	.49	.48
POT		\	.48	.49	.49	.49	.51	.50	.50	.50	.50
HIN	.45	.45	\	.00	.00	.00	.05	.01	.01	.03	.00
MAM	.47	.47	.00	\	.03	.00	.04	.00	.02	.00	.00
SCH	.35	.35	.00	.03	\	.00	.03	.02	.02	.02	.00
FEL	.43	.43	.00	.00	.00	\	.03	.02	.02	.02	.00
DON	.54	.54	.05	.04	.00	.03	\	.00	.01	.	.00
LKF	.49	.49	.00	.00	.00	.02	.00	\	.02	.01	.00
CTO	.57	.57	.01	.02	.01	.02	.01	.01	\	.01	.01
MRE	.47	.47	.03	.00	.01	.02	.00	.01	.00	\	.00
HUM	.36	.36	.00	.00	.00	.01	.00	.00	.00	.00	\

Figure 3-8. Performance Prediction--Busy Hour Display

TRUNK TO

		CDB	POT	HIN	MAM	SCH	FEL	DON	LKF	CTO	MRE	HUM
R	CDB	\		ALARM			OLOAD				+	
E	POT		\	ALARM			OLOAD				+	
P	HIN	ALARM	ALARM	\	+		+	+	+			+
O	MAM			+	\		+	+				
R	SCH					\	+	+	+			
T	FEL	OLOAD	OLOAD	+	+	+	\	+	+	+	+	
E	DON			+	+	+	+	\	+	+	+	+
D	LKF			+		+	+	+	\		+	
	CTO						+	+		\	AMBER	
B	MRE	+	+				+	+	+	AMBER	\	+
Y	HUM			+				+			+	\

Figure 3-9. Trunk Status Summary Display

CED	POT	HIN	MAM	SCH	FEL	DON	LKF	CTO	MRE	HUM
CED$	POT$	---	MAM	LKF	FEL	DON	LKF	DCC	MRE	HUM
POT$!	CED$!	---	---*	FEL	MAM	MAM	FEL	***	FEL	DON!
FEL	FEL	---	---*	---*	---*	FEL	---*	***	---*	MRE
MRE	MRE									

2.4.X OTHER SWITCH ROUTING CONTROL DISPLAYS

2.0 SWITCH STATUS SUMMARY

Figure 3-10. Routing Control Display for Hillingdon

route and typing over it with the name of another route. If the controller simply wants the processor to pick another route, blanks can be input. Typing a blank onto a manual override indicator returns the route to automatic adaptive control.

The automatic adaptive routing recommended for AUTOVON is a particularly simple form. Its purpose is to guarantee that there is an operating route available to critical subscribers homed on a given switch as long as any transmission resources are available to the switch. As described in Section 4, the adaptive routing routine is exercised at ACOC whenever a trunk group failure is detected. In response to a failure, the routine selects the next alternate route from a preengineered list of alternates, checks it for reasonableness, and then implements it by sending routing change messages to the switches.

Another automatic control routine, causing the automatic inhibition of alternate routes as a function of traffic level, is also recommended. The only phenomenon in a circuit switched network requiring traffic controls is the thrashing phenomenon in which a large part of the network trunking capacity is being held by call attempts which will be blocked. It is brought on by heavy traffic either at a particular point in the network or generally throughout the network. When traffic is heavy, more calls try multiple alternate routes, increasing the average time a MFT/RSJ pair is held in the originating switch. In addition, the heavy originating load causes a high level of demand for RSJs. This results in increasing delays for tandem traffic from other switches in obtaining an RSJ. This increasing delay reflects around the network until calls start to time out waiting for the RSJ. This would be seen as "failure to receive start signal" at the

originating switch. As the situation develops, more trunks and RSJs are occupied by calls sitting and waiting for a distant end RSJ, thereby decreasing the capacity of the network both to set up and to carry traffic.

Any control which can reduce the ineffective time that a call occupies a RSJ will delay the onset of the thrashing phenomenon. An effective and easy way to implement control, which does not defeat the multilevel precedence system, is automatic inhibition of alternate routes or primary-only routing. In this control, the occupancy of each trunk group is sensed over a very short interval, like five minutes. While this time span is much too short tc determine anything about the underlying statistical process, it can be used to determine the instantaneous loading. If the group is busy over the time interval, only primary routes which use the group will be permitted to make attempts on the group during the following interval. Secondary and tertiary routes which ride the group will be blocked at their origins.

This control tends to minimize the set up time, without significantly increasing blocking, by reserving the remaining group capacity for primary routed users. This allows the switches to handle a greater number of calls and prevents tying up the network resources while waiting for a switch. During the time that primary-only routing is implemented, the blocking probability for critical users on certain routes will be slightly increased. However, this increase is certainly less than the increased blocking due to a large number of attempts at lower priorities tying up the switch. This control is also applied and relieved quickly, so that unnecessary network throttling is avoided.

This set of manual and automatic controls can be practically implemented on the 490L network and provide sufficient control capability to maintain effective operation of whatever AUTOVON resources remain operational in the stress condition.

SECTION 4

HARDWARE AND SOFTWARE FOR CONTROL IMPLEMENTATION

4.1 SUMMARY OF RECOMMENDED SYSTEM DESIGN

The new hardware recommended as a result of this study is summarized in Table 4-1. The major items of new hardware are the CRU and the computer system at ACOC. Section 4.2.1 provides a detailed description of the function of the CRU and the specific capabilities of a feasibility demonstration model being developed by Rome Air Development Center (RADC). The computer system at ACOC is a minicomputer with associated peripheral devices. The components for the recommended configuration are shown in Table 4-2.

Software additions and modifications are summarized in Table 4-3. The size estimates for these subsystems are shown in Table 4-4. Within the preexisting system control subsystems, only very minor changes are needed. ATEC needs to be modified to accommodate communications with ACOC and the DSCS/CS TCE. The AUTODIN II SNCC is a duplicate of the NCC, modified to relay status reports to the CONUS NCC. The RAMM has a fairly significant software change which allows it to process switch status and traffic data for transmission to ACOC, manage the communications lines to the ATEC NCS, and actuate controls upon receipt of valid commands from ACOC or the local controller.

TABLE 4-1. SUMMARY OF HARDWARE MODIFICATIONS

System/Subsystem	Hardware Modification	Remarks
AUTODIN II SNCC	None	See note
RAMM	Modified to provide three new I/O ports for ACAS data, operations keyboard display unit (KDU), and ATEC interface.	See Section 4.2.2
CRU	New subsystem to provide remote control patching capability for the DCS.	See Section 4.2.1.2
DSCS--TCE	None	See note
DSCS--NCE	None	See note
ATEC--CIS	None	CIS assumed to have spare ports at sites requiring access. See note
ATEC--NCS	None	See note
ATEC--SCS	None	See note
ACOC level	New processor and peripherals to support the ACOC control functions.	

Note: Processor memory augmentation judged not to be required.

TABLE 4-2. ACOC HARDWARE COMPONENTS/PRICING

Equipment	Cost
CPU	$10,000
Memory 256 K bytes	30,350
10M byte moving head disk and controller	12,700
Magnetic tape drive and controller	11,000
Multiline communication processor with line adapters for 3 CRT terminals and 4 sync commlines	6,000
CRT/keyboard/hard copy printer 3 @ $6,485	19,455
Cabinets/power distribution/memory battery backup	3,560
TOTAL	$93,065
<u>Optional</u>	
Scientific instruction processor	$ 5,050
Mass storage disk 33M and controller	21,000
Line printer and adapter	10,440

TABLE 4-3. SUMMARY OF SOFTWARE MODIFICATIONS

System/Subsystems	Software Modifications
AUTODIN II--SNCC	Provide capability to transmit all PSN reports received to NCC-CONUS.
RAMM	Provide capability to access and process switch status and traffic parameter for transmission to ACOC at appropriate timing intervals. Provide interface to ACAS data, an operations KDU, and an ATEC node.
DSCS--TCE	Compute historical profiles for EIRP and RSS parameter, file for local display, provide alarm thresholds for operator alerting, transmit periodically to NCE. Report earth terminal status alarms to ATEC-CIS using ATEC 10000 formats and protocol. Report alarm exception reports to NCE.
DSCS--NCE	Receive and file EIRP and RSS historical profiles for local display, transmit to ACOC. Receive exception report from TCE record in data base, update display and transmit to ACOC.
ATEC--CIS	Message routing tables modified to accommodate messages to and from TCE, to and from ACOC.
ATEC--NCS	Message routing tables modified as in ATEC CIS. Process TCE alarm message for correlation with terrestrial alarms, store faults, transmit uncorrelated faults to sector.
ATEC--SCS	Message routing tables modified as in ATEC-CIS, transmit and receive message from ACOC on AUTODIN. Process TCE alarm messages from node store and attempt correlation with terrestrial alarms.
ACOC/WWOLS	New software system to perform system control functions at the theater level.

TABLE 4-4. SYSTEM/SUBSYSTEM SOFTWARE SIZING SUMMARY

System/Subsystem	Number of Instructions	Storage (bytes)	
		Program	Data
AUTODIN II SNCC	25H	375	--
RAMM	955H 230A	15,015	250
DSCS--TCE	235H	3,525	100
DSCS--NCE	210H	3,150	200
ATEC--CIS	30H	450	--
ATEC--NCS	275H	4,125	--
ATEC--SCS	235H	3,525	--
ACOC/WWOLS	20025H	*	*

* See Table 4-5.

The software size for the new ACOC/WWOLS processor is shown in Table 4-5. A description of the software making up this estimate is in reference 2 and Sections 4.4.1.1, 4.4.2.1, and 4.4.3.1 of this report. Table 4-6 shows an estimate of the data base size for the data base described in Sections 2 and 3 of this report.

TABLE 4-5. MEMORY REQUIREMENT FOR ACOC

Element	Resident	Support Overlay	Largest Functional Overlay	Total Occupancy (bytes)
Theatre	15,750	23,475	9,750	48,975
Connectivity	15,750	32,245	47,850	95,845
AUTOVON control	15,750	27,375	18,000	61,125

Operating system	22,000
System pool	20,000
Data base management	20,000
	62,000 Bytes
Total Memory Required	157,845 Bytes

TABLE 4-6. THEATRE DATA BASE SIZING

	Record Size Bytes	Number of Records	File Size Bytes
Network Control			
Sector file	39	5	195
Node file	42	30	1,260
Station file	218	100	21,800
Connectivity path file	331	25	8,275
Link file	257	410	105,370
Trunk file	670	1,250	837,500
Circuit file	218	10,500	2,289,000
Fault file	192	3,600	691,200
Network connectivity display (19 displays) Form	1,920	19	36,480
Input-packed	600	19	10,400
AUTOVON Control			
Network configuration file	2,342	1	2,342
Switch equipment status and historical file	234	9	2,106

TABLE 4-6. THEATRE DATA BASE SIZING (concluded)

		Record Size Bytes	Number of Records	File Size Bytes
AUTOVON Control (continued)				
SW configuration table		630	9	5,670
SW traffic file		30	9	270
Trunk group status file		903	25	22,575
Trunk traffic file		78	25	1,950
Critical user access status		30	100	3,000
VON displays (26 displays)	Form	1,920	26	49,920
	Input-packed	600	26	15,600
Theater Control				
Theater displays (6 displays)	Form	1,920	6	11,520
	Input-packed	600	6	3,600
AUTODIN Control				
Summary display (4 displays)	Form	1,920	4	7,680
	Input-packed	600	4	2,400

4.2 HARDWARE REQUIREMENTS FOR CONTROL IMPLEMENTATION

4.2.1 The Automated Patch Network--CRUs

4.2.1.1 Functional Description of the CRU--Previous reports have alluded to the future existence of CRUs at station level which would automate the patching function. Although these devices are not required as part of the proposed network control, they have been addressed as to their impact on control implementation. A short description of a feasibility demonstration model of a CRU currently being developed by RADC is given here as it relates to system control.

The CRU is designed to provide remotely controlled patching of DCS circuits and groups. The unit performs this function by time-division manipulation of channel data words. Thus, it can provide channel or group patching without requiring all levels of multiple hierarchy to be present for every group. It can carry out this patching activity without local site manning due to its computer interface capability with remote control sites.

Inside the CRU, the groups presented to the ports are broken down into channels and the resulting channel data stored in the reassignment memories. The channel data is reconfigured into groups by selectively reading the reassignment memories. The sequence of reading the memories (and hence the channel reassignments) is programmed into the CRU hardware by the CRU control computer. Frame bits are added to the newly assembled groups and the result outputted from the CRU. In this manner, a single channel from any input group may be output onto any output group. Both

T1 and tri-services tactical communication system (TRI-TAC) groups can be handled in this way. In addition, T1 to TRI-TAC group conversions are possible in the CRU to provide DCS/TRI-TAC interfaces.

The level of the CRU in the DCS multiplex hierarchy is shown in Figure 4-1. The CRU will interface DCS transmission facilities at the group and channel levels. TRI-TAC interface will take place on group, channel, and subchannel levels. The CRU will be able to make non-blocking patches at all levels. In addition, the CRU will be able to multiplex locally incoming T1 and TRI-TAC channels into groups. The CRU will also act as an interface unit between the DCS and TRI-TAC multiplex hierarchies by allowing channels from either family to be re-formatted for the other's group multiplex.

Figure 4-2 depicts the configuration of the transmission plant using CRU. The CRU replaces the equal level patching bay at the station level. Transmission facilities that enter the station terminate on the CRU ports from which they are time-division patched to the appropriate output from the station. The connectivity will reside in the CRU time switching pattern rather than a patch bay of cables.

Control for the CRU is normally effected via the ATEC CIS. This unit will interface with the CRU's control computer over a 150 baud link providing all levels of system control access to the CRU's control computer. Commands such as patching new connectivity for altrouting, CRU port redefinition, connection of spare CRU port equipment, and testing of CRU modules will pass over the ATEC/CRU interface. Alternatively, the CRU control computer can be accessed via the station CTS or from a dedicated KDU if no CTS is available. Thus the CRU is controllable from automatic and manual, remote and local control interfaces.

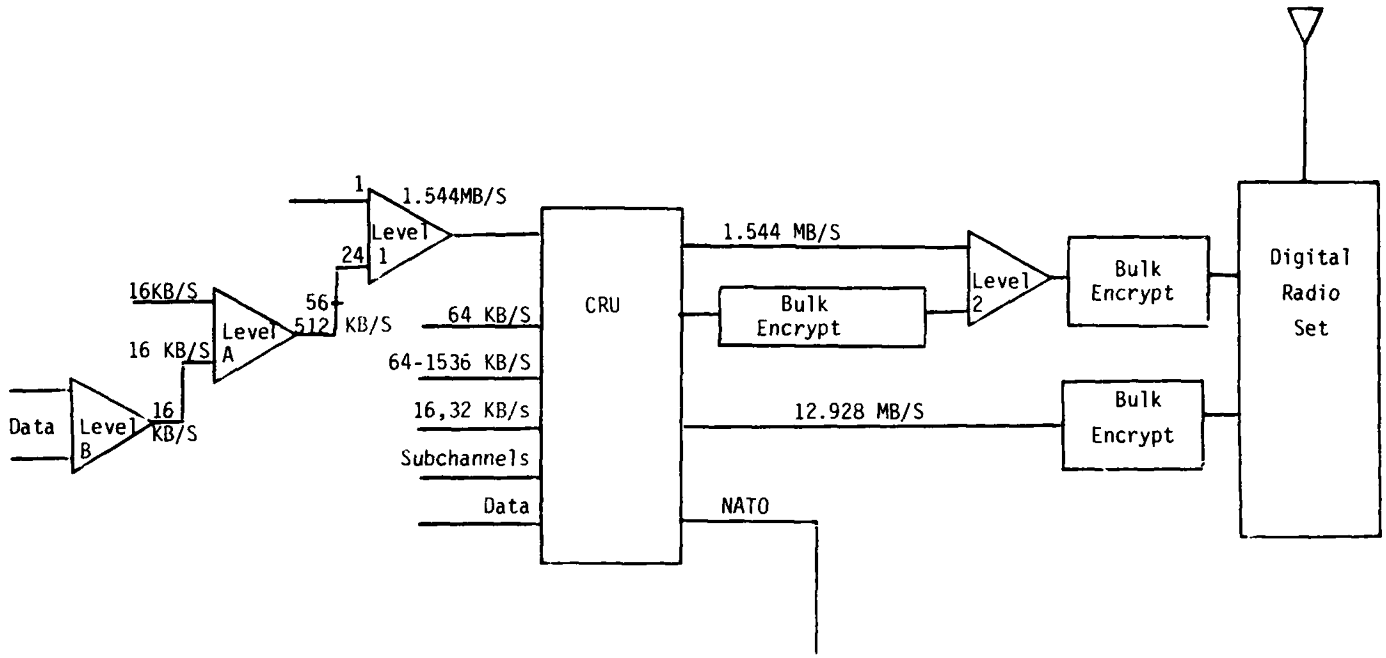


Figure 4-1. CRU in the DCS Multiplex Hierarchy

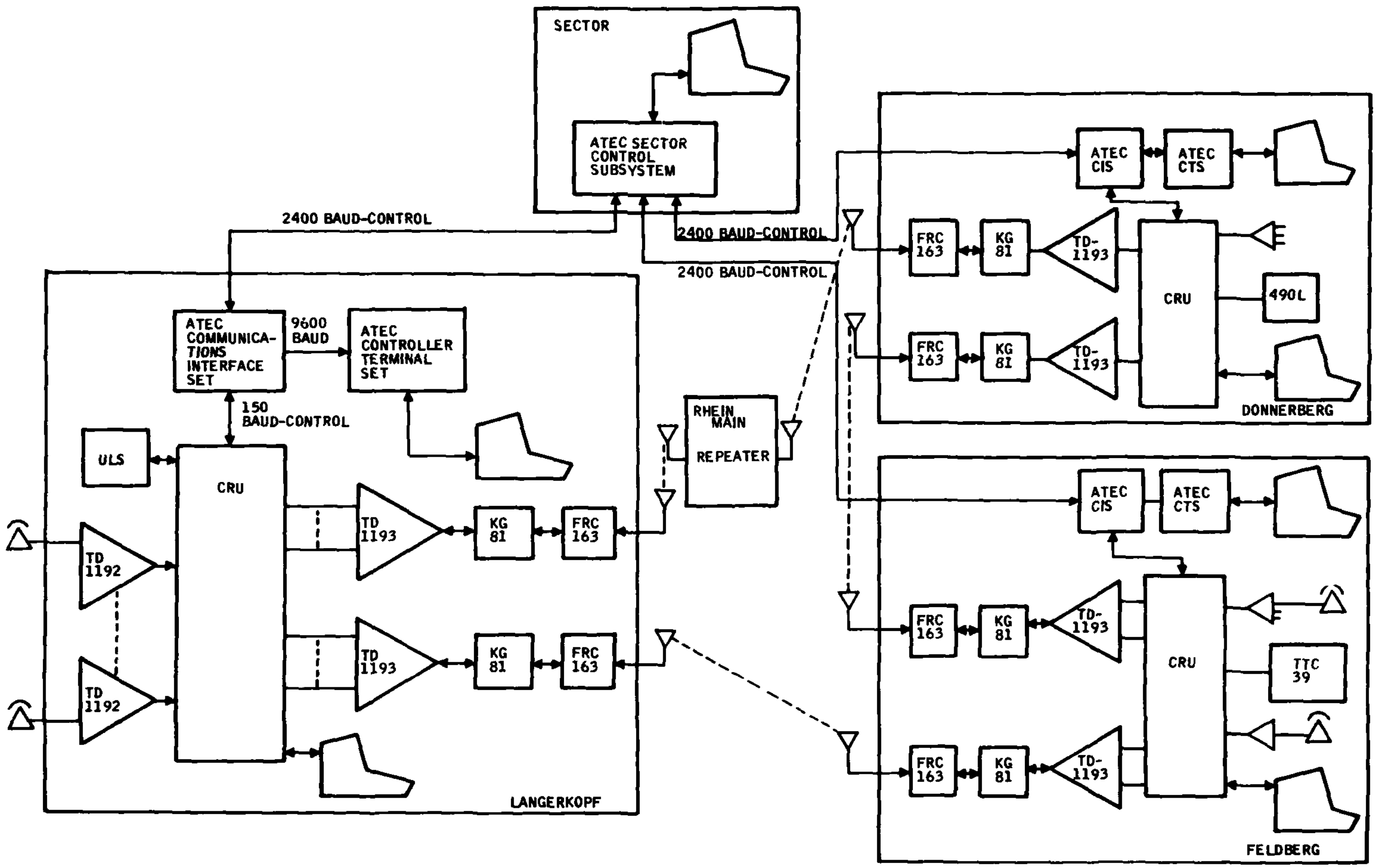
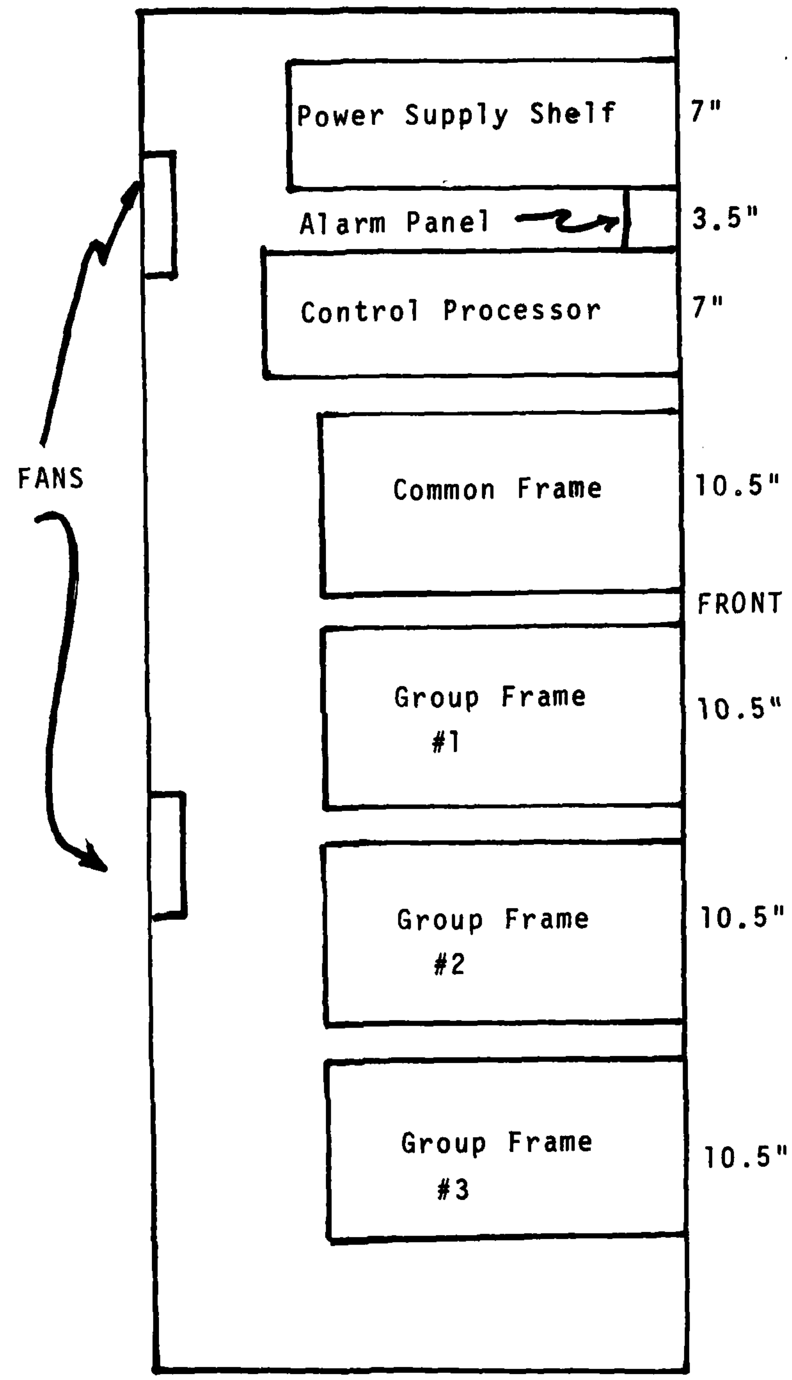


Figure 4-2. CRU in the DCS

One important effect that CRUs will have upon the DCS is increased available connectivity. In the current network, patching of channels can take place only at locations where the channels have a voice frequency (VF) appearance. In order to provide full patching capability at a station, the station would require 2 second-level multiplexers, 16 channel banks, and some number of sub-channel multiplexers for every link terminating at the station. With the CRU, full patching capability is achieved without this number of multiplexers at each station. In addition, the coding and decoding noise that would be created by channel bank coding of VF circuits is avoided due to the coded time-division patching of the CRU.

With full patching capability at each station, the trunks normally described in the DCS network are all shortened to one link for patching purposes. The drop of a channel will still require a channel bank, but each circuit will only require one at each end rather than at every patch station. This increase in connectivity will prevent route "backhauling" as is currently seen in the DCS. It will also simplify the altroute search algorithms described in report 3.

4.2.1.2 The CRU Cost Estimate--A budgetary cost of 50 CRUs has been estimated. The basis for this estimate was obtained from data gathered from the RADC contract on which three feasibility models are being developed. The configuration and functions currently being incorporated in the feasibility models are those selected for the cost estimate. Parts lists are available for the various components which make up the system and have been used to arrive at parts costs. Figure 4-3 shows a side view of the rack assembly and depicts the components that have been included in this cost estimate. The overall cost of a single unit is basically a function of the number of



Side View

Figure 4-3. CRU Rack Assembly

group frames that are required in the actual deployment in specific DCS stations. To determine the deployment configurations required, the DCS stations in Europe were examined. The results are in Table 4-7. Each group frame can accommodate up to 40 groups. Each station was examined to determine the DCS requirements using the multiplex configuration and DCS connectivity projected for 1985. A group frame was allocated for every 30 T1 groups allowing 10 additional inputs to be connected (TRI-TAC groups or other channels). The production quantity of 50 includes the 37 configurations requiring two or more group frames plus 13 which require only a single group frame. It is assumed that the initial deployment will include all of the major DCS stations. The cost of each CRU configuration has been computed taking advantage of a production quantity of 50 units requiring a total of 105 group frames.

The cost is based on the following assumptions:

- Parts have been selected and prices based on components meeting full military specifications.
- Production costs do not include acquisition non-recurring costs such as preparation of documentation, drawings, schematics, manufacturing assembly drawings, manufacturing assembly procedures, and various board, unit, system checkout and test procedures, and operating or test software.
- All boards are tested automatically, but the non-recurring cost to develop this capability is not included in the production price.
- All prices are FOB at manufacturer's facility.

TABLE 4-7. CRU CONFIGURATIONS

Configuration Number	Number of T1 Groups	Number of Group Frames	Number of Stations Requiring Configuration
5	>120	5	2
4	91 to 120	4	3
3	61 to 90	3	6
2	30 to 60	2	26
1	<30	1	All other stations in Europe

- All costs include manufacturing and engineering overhead (90%), general administration (17%), and fee (10%).
- All costs are quoted assuming a one-year production effort with a mid-point of January 1980.

The components which make up the costs are shown in Table 4-8 together with the total price of a CRU configured with a single group frame. Additional configuration costs are obtained by adding an increment of $15,942 for each additional group frame required. This cost is the sum of the group frame and a modular power supply assembly. A cost of a configuration #5 CRU is therefore $102,842.

The composite total production cost of 50 CRUs is:

Configuration Number	Quantity	Unit Cost	Extended Cost
1	13	39,074	507,962
2	26	55,016	1,430,416
3	6	70,958	425,748
4	3	86,900	260,700
5	2	102,842	205,684
		TOTAL	2,830,510

4.2.2 AUTOVON Control Hardware

4.2.2.1 Switch Site Hardware Candidates--The design of the 490L switch does not adequately support real-time system control. External hardware

TABLE 4-8. INDIVIDUAL COST COMPONENTS

Item	Cost ($)	Configuration #1 Cost	Remarks
1. Equipment Rack	481	481	See note
2. Alarm/Control Panel	116	116	See note
3. PS Shelf		2221	Includes two modular PS assemblies (one for the common frame and one for the group frame).
• Card cage and back plane with cables	569		
• Modular power supply board and assembly	826 each		
4. Common Frame Shelf		3848	See note
• Card cage and back plane with cables	569		
• Spare reassignment network (RAN) board	1081		
• Subchannel reassignment network (SCRAN) board	786		
• Timing board	1412		
5. Group Frame Shelf		15,116	Assumes full 16-board complement (5 Rcvr. Bds, 5 IMs, 5 OMs and 1 RAN).
• Card cage and back plane	1080		
• Receiver board	838 each		
• Inlet multiplexer (IM)	967 each		
• Reassignment network (RAN) board	1081		
• Outlet multiplexer (OM)	786 each		
6. Control Processor	10480	10,480	See note
7. Production Management and System Integration and Test	6812 per system	6,812	Includes Production Control, Production Engineering, Quality Assurance, Collateral Engineering, System Integration/Assembly and System Level Tests. (Total cost divided by 50.)
	TOTAL	39,074	

Note--Cost is the same in all configurations.

is required to sense the status of the switch and to implement control actions received from a centralized control facility. The candidates for switch site hardware are the following:

- ACAS (AUTOVON Centralized Alarm System)
- TDCS (Traffic Data Collection System)
- RAMM (Rapid Access Maintenance Monitor)
- New developments

The ACAS senses the state of several parameters (see Table 3-2) via individual sense leads from the switch. As the system is currently used, the sensed data is blocked and transmitted to ACOC over dedicated 75 baud telemetry lines every two seconds. The data is read into latches at ACOC and displayed on a panel of pilot lights. There is no processing or memory capability associated with ACAS. Because the display is a direct display of switch state, rather than an alarm display, it is difficult for controllers to interpret. It is therefore not useful as a component of system control. The status information sensed at the switch is, however, quite basic to system control. This data should be collected and preprocessed by the switch site processor so that ACOC can be informed of any significant events implied by it.

TDCS is a minicomputer based system intended for collection of long-term engineering data. The processor is a Lockheed SUE computer interfaced to the switch memory and several status leads. TDCS operates in one of three modes: rapid memory reload, routine data collection, or quick-look data collection. Because of the processing load, TDCS can only operate

in one mode at a time. Rapid memory reload provides a means to load the switch memory from magnetic tape. It has been the most used mode in the past, but this function is being superceded by the RAMM which has more extensive memory manipulation capabilities.

In the data collection modes, TDCS collects extensive traffic and status information from the switch as shown in Table 4-9 (Reference 6). Most of the detailed traffic information is derived by tracking the operation of the switch RSJs. This tracking requires a large amount of detailed data manipulation and accounts for the load which restricts TDCS to one mode at a time. When operating in data collection mode, TDCS writes the data onto a magnetic tape. It also has a capability to automatically dial up a processor at ACOC, and dump the data at 1200 baud.

TDCS seems to be subject to several problems which prevent its use as a system control component. Reference 7 claims that TDCS is a very temperamental piece of equipment because of not operating a large portion of the time and operating with questionable accuracy the rest of the time. If this availability problem is not solved, TDCS cannot be considered for future applications. The SUE minicomputer is no longer manufactured or supported by Lockheed, so maintenance problems will be increasing as the equipment ages. The protocol used on the dialup telemetry does not have significant error protection. In the past, this has prevented the use of the telemetry as the circuits are not good enough to provide error-free data transfer. Finally, the man-machine interface at ACOC is not usable for real-time control since it merely dumps a large block of data without any alarm thresholding, formatting, or data control capabilities.

TABLE 4-9. TDCS DATA COLLECTION ITEMS

	Lead		Lead
Traffic Data by Trunk Group (110 Groups)		DTMF Receiver (15 Receivers	
Originating attempts		Out-of-service count	X
Terminations		Out-of-service duration	X
Preemptions		All DTMF Receivers	
Non-Preemptive overflow		Attempts count	
Preemptive overflow		Usage	X
Usage	X	Overflow count	
All trunks busy count (30 Groups)	X	MF 2/6 Transceiver (15 Transceivers)	
All trunks busy duration (30 Groups)	X	Out-of-service count	X
Traffic Data by Destination		Out-of-service duration	X
(200 Destinations)		All MF 2/6 Transceivers	
Voice grade		Attempts count	
Special grade		Usage	X
Counts		Overflow count	
Local attempts		All Register-Senders Busy	
Line permanent signal		Count	X
(time outs)		Duration	X
False start		All DTMF Receivers Busy	
Partial Dial		Count	X
Timed out		Duration	X
Call abandoned		All MF 2/6 Transceivers Busy	
Intra-office attempts		Count	X
(local terminations)		Duration	X
Local Voice Grade Calls		Heavy Traffic	
Local Special Grade Calls		Count	X
Incoming Attempts		Duration	X
Tandem Attempts		Pilot Make Busy (30 Pilots)	
Trunk Permanent Signal		Count	X
(time outs)		Duration	X
Preemption Exercised		Line Load Control Class	
Voice grade		(3 Classes A, B, and C)	
Special grade		Count	X
No Start Signal Indicator		Duration	X
Preemption Failed, Voice Grade		Switch Marker (2 Markers)	
Preemption Failed, Special Grade		Out-of-service count	X
Routine Overflow		Out-of-service duration	X
Voice grade		Logic (3 Logics)	
Special grade		Out-of-service count	X
Traffic Data by Register-Sender		Out-of-service duration	X
(24 Register-Senders)		DSA Position/Link (20 Links)	
Attempts		Position count	X
Usage	X	Position usage	X
Out-of-service count	X	Link group busy count	X
Out-of-service duration	X	Link group busy usage	X
DSA Marker (2 markers)		All links busy count	X
Out-of-service count	X	All links busy duration	X
Out-of-service duration	X		
Memory (2 memories)			
Out-of-service count	X		
Out-of-service duration	X		
Answer Time Recorder			
Calls sampled	X		
Calls answered	X		
Calls not answered			
Traffic Data by DSA Class (5 Classes)			
Attempts			
Overload counts	X		

Hampering any modification of TDCS is the fact that the software design uses a custom executive (no operating system is used), and the coding is directly done at the absolute assembly level. Therefore, any modifications would be difficult and costly.

In spite of all its deficiencies, TDCS provides extensive traffic collection capabilities. If the difficulties could be overcome, it would be very valuable to use the RSJ tracking capabilities of TDCS to collect basic traffic data as an input to a local system control processor. This would relieve the system control processor of a major computational burden. However, because of the difficulties experienced with TDCS in the past, that recommendation cannot be made. If the maintenance problems are solved, TDCS should be considered for low-level traffic parameter sensing.

The newest piece of AUTOVON equipment is the rapid access maintenance monitor (RAMM). The RAMM is a replacement for the original electromechanical maintenance monitor. Its primary purpose is to interpret trouble card data from the switch BITE in order to simplify the maintenance and repair tasks. It also provides a capability to reload the switch memory from disk. The RAMM consists of a Data General NOVA 3D minicomputer, 96K words of memory, moving head disk, tapes, and hardware to interface with the switch. The system is run under DG's RDOS, a well known foreground/background multitasking operating system. All current programs are written in FORTRAN, and current tasks occupy about 33% of the processor's time.

Because the RAMM's primary purpose is aiding the diagnosis of switch malfunctions, it is a superior source of switch status information. Since

it can read and write in the switch memory, it has the capability to collect traffic data and to modify routing tables, translation tables, etc. It has an efficient multitasking operating system and has the capability to collect all sources of switch data and communicate with a local supervisor and with ACOC.

4.2.2.2 Recommended Hardware Configuration--The recommended hardware configuration for system control of AUTOVON is shown in Figure 4-4. It is based upon use of the RAMM as the primary information processing system at the switch site. ACAS telemetry lines are connected directly to the RAMM, rather than to telemetry circuits. This provides the basic traffic monitoring capability to the RAMM. It may be redundant with other interfaces already present in the RAMM, but this could not be determined from available RAMM documentation. If this interface turns out to be redundant, there is no need to use any ACAS equipment.

A new keyboard/display unit has been added to the RAMM for use by the operations supervisor. From this KDU, the operations supervisor can manipulate switch tables to implement controls and can communicate with ACOC via text messages. Also added is a 2400 baud commline into the ATEC NCS. The NCS port was selected rather than a 150 baud CIS port for the following reasons:

- There is a NCS colocated with every 490L switch.
- Switches are located in large stations whose CIS ports are heavily loaded otherwise.
- 150 baud is only minimally adequate.

The ATEC system does no processing of AUTOVON information but does provide message switching service for telemetering to/from ACOC.

If TDCS is proven practical, it can also be interfaced to the RAMM using the TDCS 1200 baud port, adding another 1200 baud port to RAMM. No other hardware modifications to RAMM are needed.

The hardware required at ACOC is the system control processor shared with other system control functions. It may be desirable to dedicate a keyboard/display to the AUTOVON function, but otherwise the hardware is as described in reference 2.

4.2.2.3 Hardware Cost Estimate--The recommended modifications to the Rapid Access Maintenance Monitor are depicted in Figure 4-4. These modifications include an operations keyboard display terminal for handling text messages to and from the ACOC System Control Processor, determining 490L switch status, and modifying the switch memory. Modifications also include processor interfaces to accommodate the new KD terminal, a 75 baud asynchronous data input to collect ACAS data, and a 2400 baud synchronous ATEC interface for upwards reporting. The CRT selected is a Data General Model 6053 alphanumeric video display terminal with detachable keyboard. This unit provides selectable speed (110 to 19.2K baud), standard EIA or 20ma interface, 11 key data entry pad, 8 function keys, 64 character set (ASCII upper case), 24 line x 80 character screen, direct cursor positioners, character blink, and provisions for optical hard copy printer. The unit is priced at $1990 each. The interface requirements can be satisifed with a single multi-line communication interface. A Data General Model 4243 interface has been selected. This interface provides

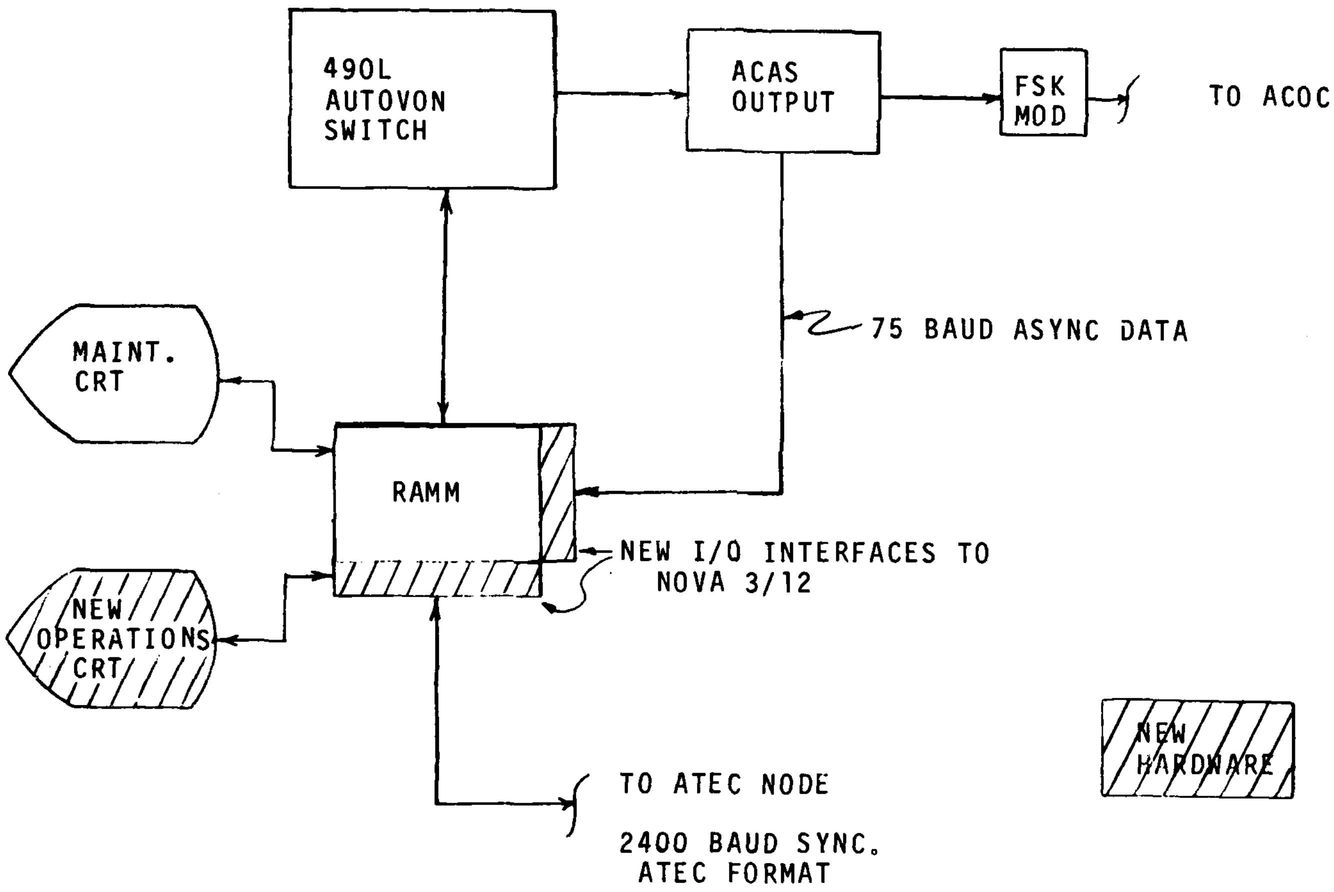


Figure 4-4. Hardware Modifications to RAMM

a functional combination of a Model 4241 four-line asynchronous subsystem plus a Model 4242 one-line synchronous controller subsystem. The 4243 is priced at $2700 each. The total added hardware cost for each RAMM subsystem is $4690. The total cost for nine 490L switches and the associated RAMM subsystem is (9 x $4690) $42,210.

4.3 COMMUNICATIONS REQUIREMENTS FOR TRANSMISSION CONTROL

4.3.1 Overview

Communications requirements for implementing altrouting are determined by the nature and location of the activities involved. The station level of the system control hierarchy is the level at which patching is actually implemented since it is the only level that actually connects to the transmission system. The altroute and normalization algorithms are performed at ACOC for the following reasons:

- ACOC has full visibility of all data needed to perform altrouting including a data base, ATEC fault isolation reports, and DSCS/CS status reports.
- No excessive message traffic is created by performing altroute generation at ACOC.
- Making all altroute generation occur at the highest level which has the real-time area data base makes it easier to maintain data base consistency.
- Processor time is likely to be more available at ACOC than at lower levels.

The series of implementation steps for altrouting is shown in flow chart form in Figure 4-5. The process begins with ATEC or DSCS/CS detecting a fault condition and isolating the report to some specific equipment and location. This output leads to assigning the fault to a station for ETR estimation and eventual repair. The circuit control office (CCO) notifies the user that his service is out of order. The output of fault isolation and ETR estimation is a fault file entry to the data base for the service affected. This data base update is sent to sectors and ACOC. Should the ETR be short enough that data base update and eventual altrouting would not be implemented before repair, the ACOC stores the fault report and takes no action on it. Establishing the threshold level on the ETR for this decision can be made with the help of the implementation time analysis presented in Report 3 (Section 2.8).

When the decision is made to altroute, the altroute routines are put into action to synthesize the altroutes. The patching messages required for the altroute are automatically generated and the new data base entry for the altroute created. A listing of the altroute is then presented to the altroute controller for approval. Rejection at this stage must be accompanied with some controller action (data base update or search parameter changes) so that a second run of the algorithms will yield a new altroute. When approval is finally given, the patching messages are sent out to the patching stations via ATEC telemetry. At this point, the controllers at the patching stations concur or reject the plan concerning their specific patching and preemption actions. This step is needed in order to guarantee that late or incorrect fault reports concerning the alternate route are considered just before patching occurs.

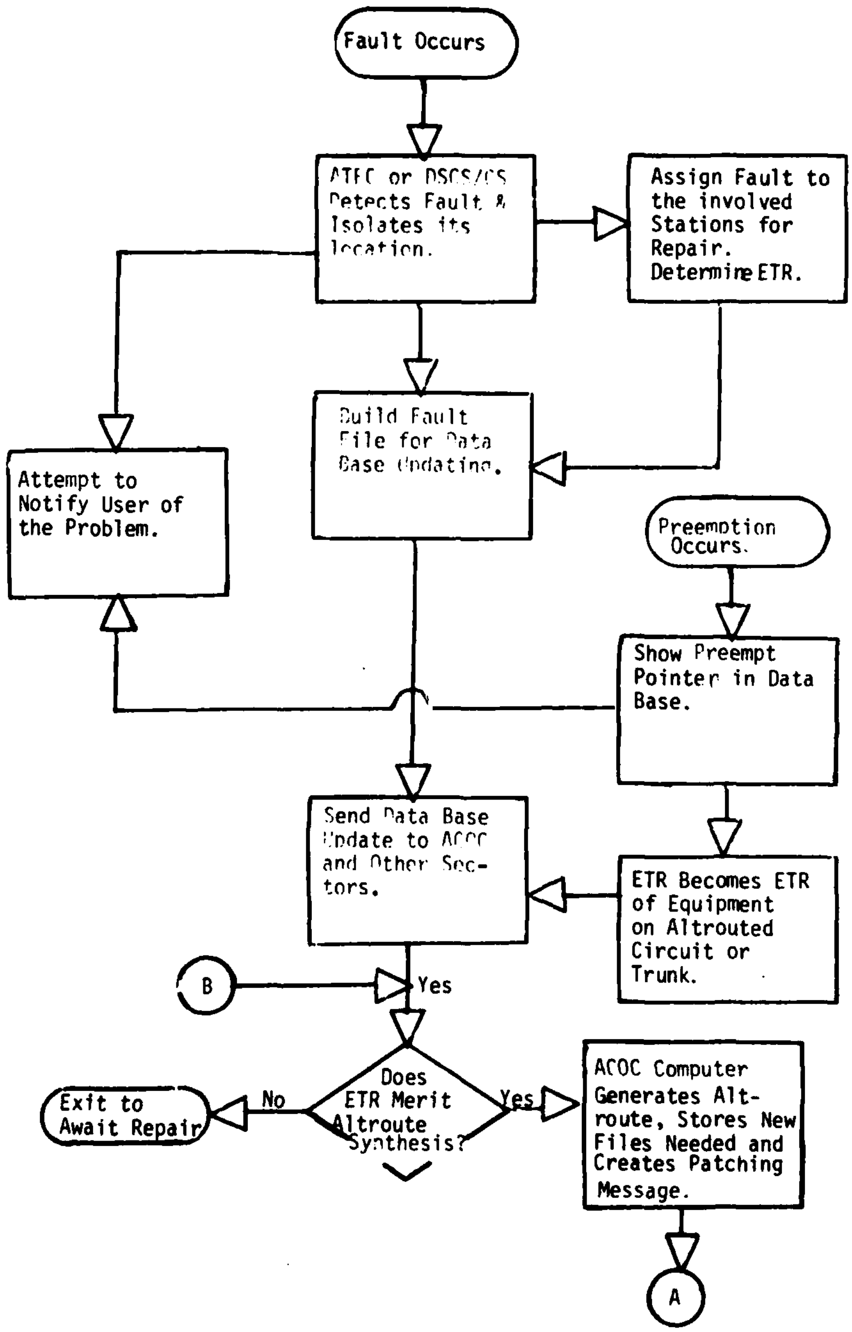


Figure 4-5. Altroute Implementation Interfacing

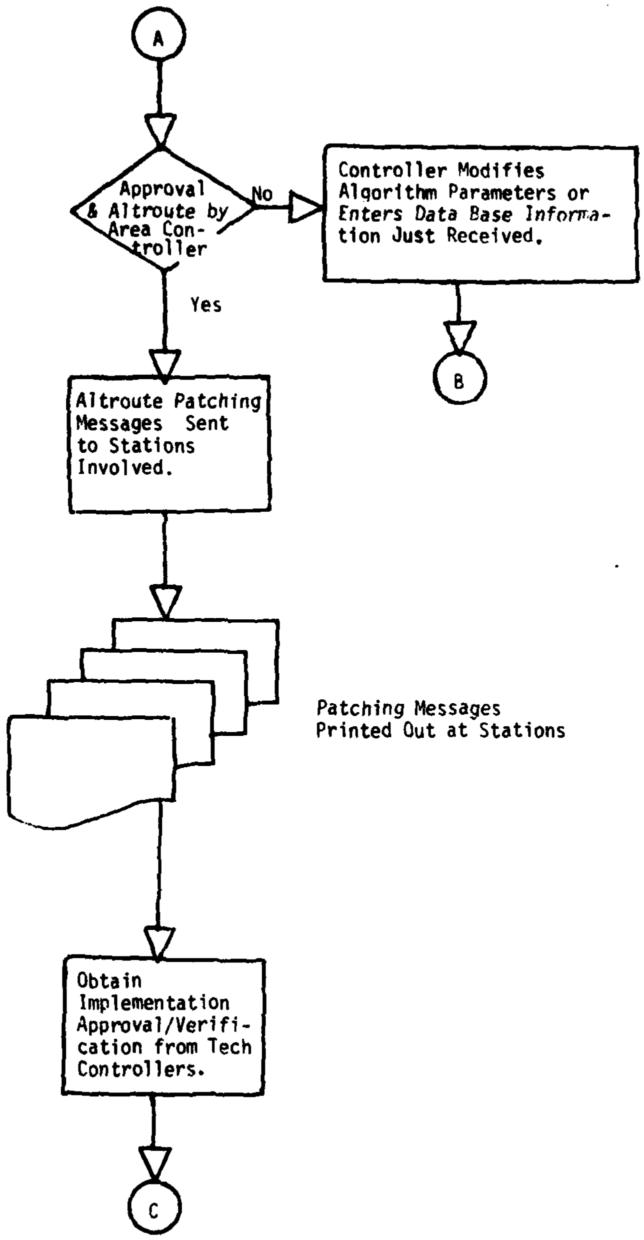


Figure 4-5. Altroute Implementation Interfacing (continued)

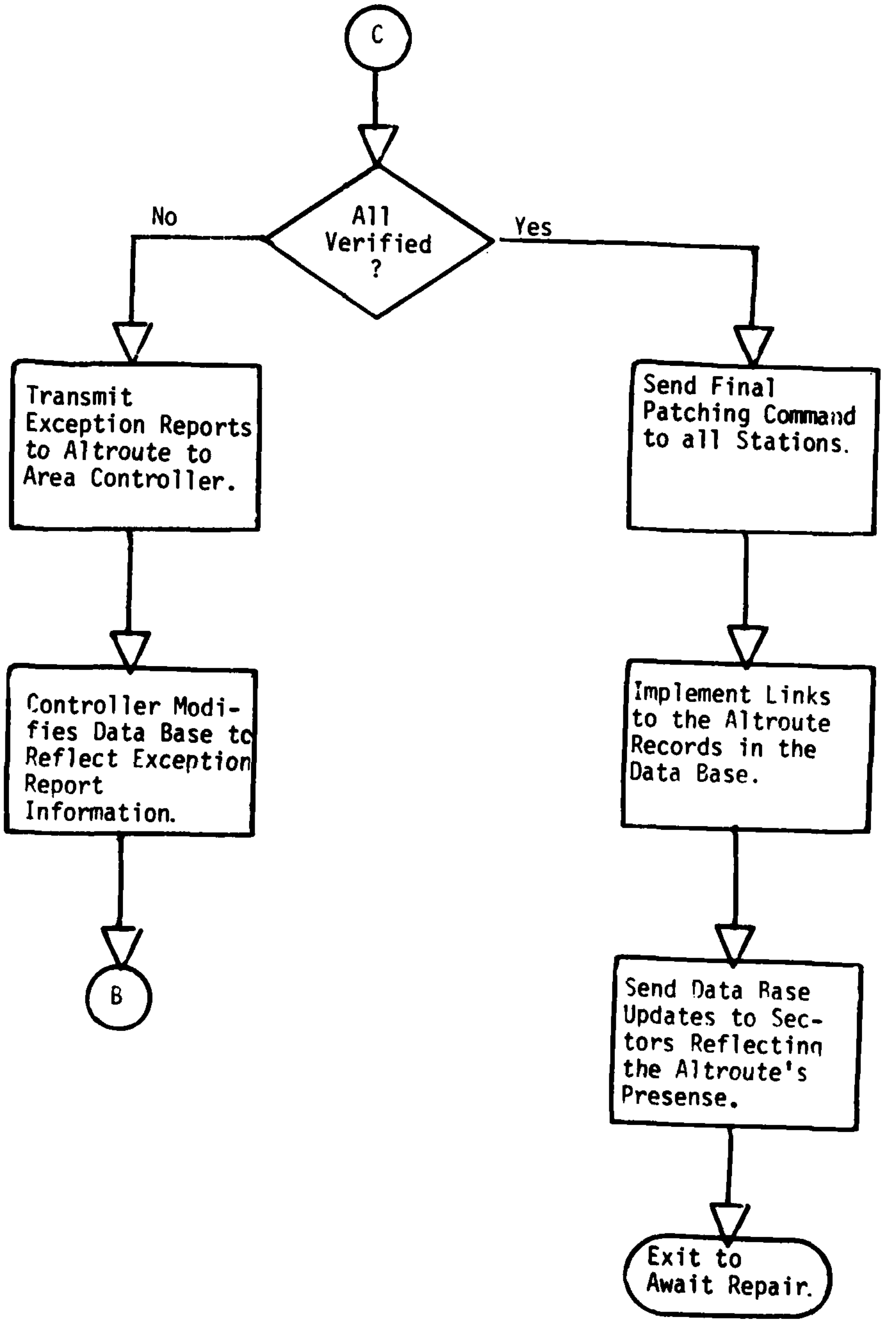


Figure 4-5. Altroute Implementation Interfacing (concluded)

Rejection of an altroute patch plan at a station must be accompanied by some explanation of why the plan fails at a particular station. If proper cooperation is being given, these reports should deal exclusively with new fault status information that ACOC has not considered. Thus, data base updating at ACOC and rerunning the altroute synthesis will follow.

When all patching stations concur with an altroute plan, ACOC will send an acknowledgment to all patching stations to implement patches. The data base links to the new altroute records are made at ACOC to reflect the altroute's presence. These data base updates are then transmitted to sectors for ATEC data base updates.

The normalization activity is basically a reverse of the altrouting; returning circuits or trunks to their normal transmission facilities form an altroute configuration. As shown in Figure 4-6 the reporting of status data triggers this activity.

The activity begins for normalization when all faults on a service's normal route are removed or all preemptions made to a service's normal route are deleted. The normalization routine operates to determine if normalization is possible and generates the data required to patch the normal route and update the data base. Report 3 gives the details of this routine. Upon generation of the normalization plan, the area controller will inspect it for accuracy and then send it to the patching stations. Each station will see the plan as it refers to its part of the route and be allowed to respond to ACOC. This gives the stations closest to the real route a final chance to examine the area computer's analysis of the action. If exceptions result due to some data in error or late to ACOC, the station will submit this timely data to

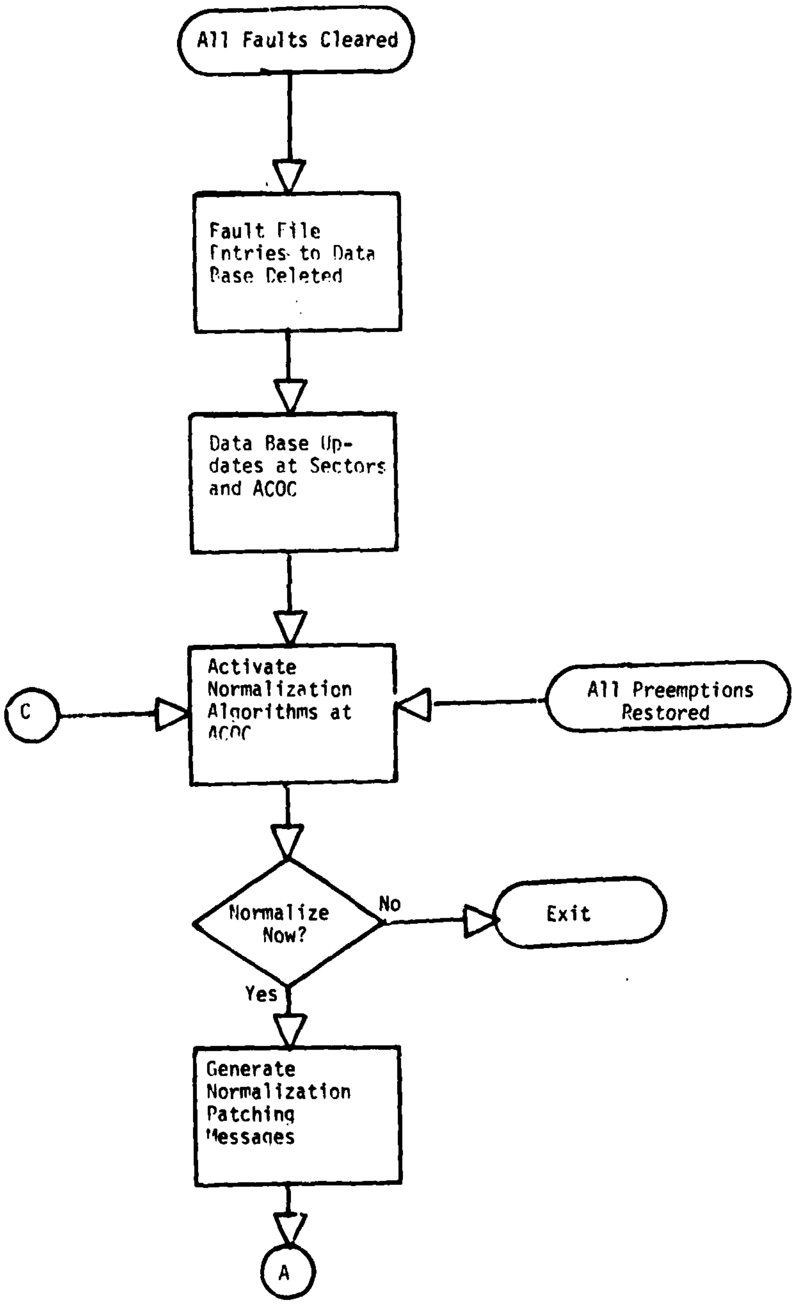


Figure 4-6. Normalization Activity

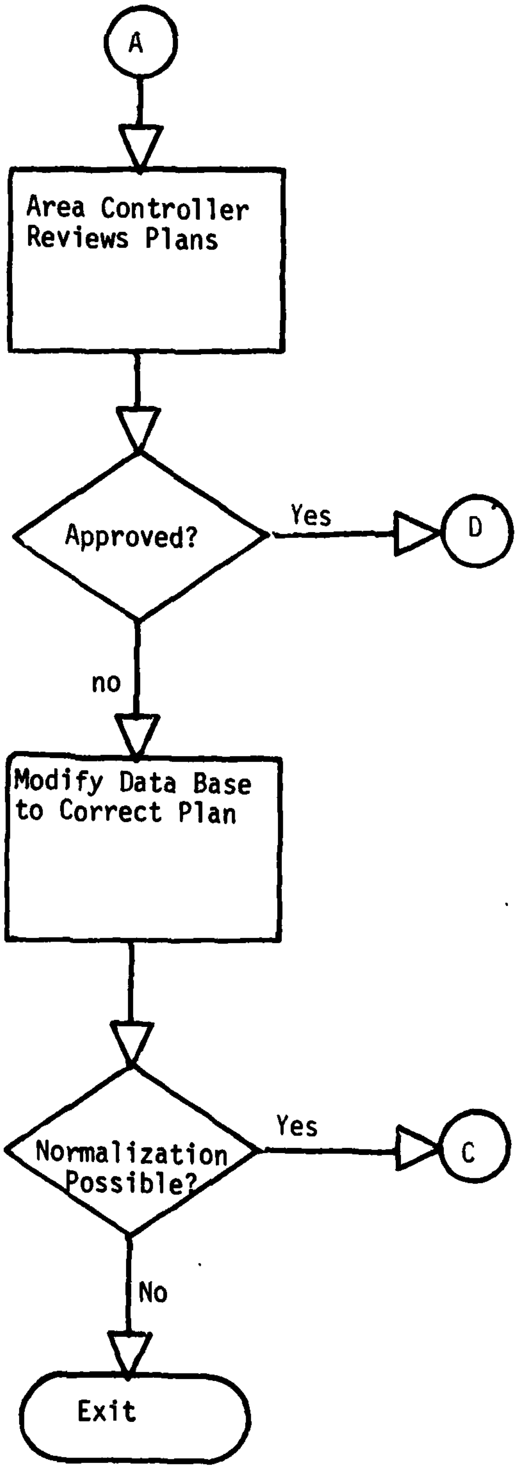


Figure 4-6. Normalization Activity (continued)

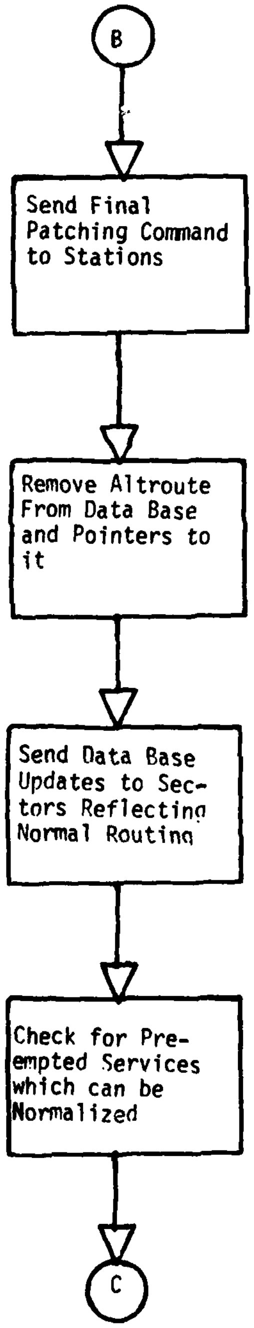


Figure 4-6. Normalization Activity (continued)

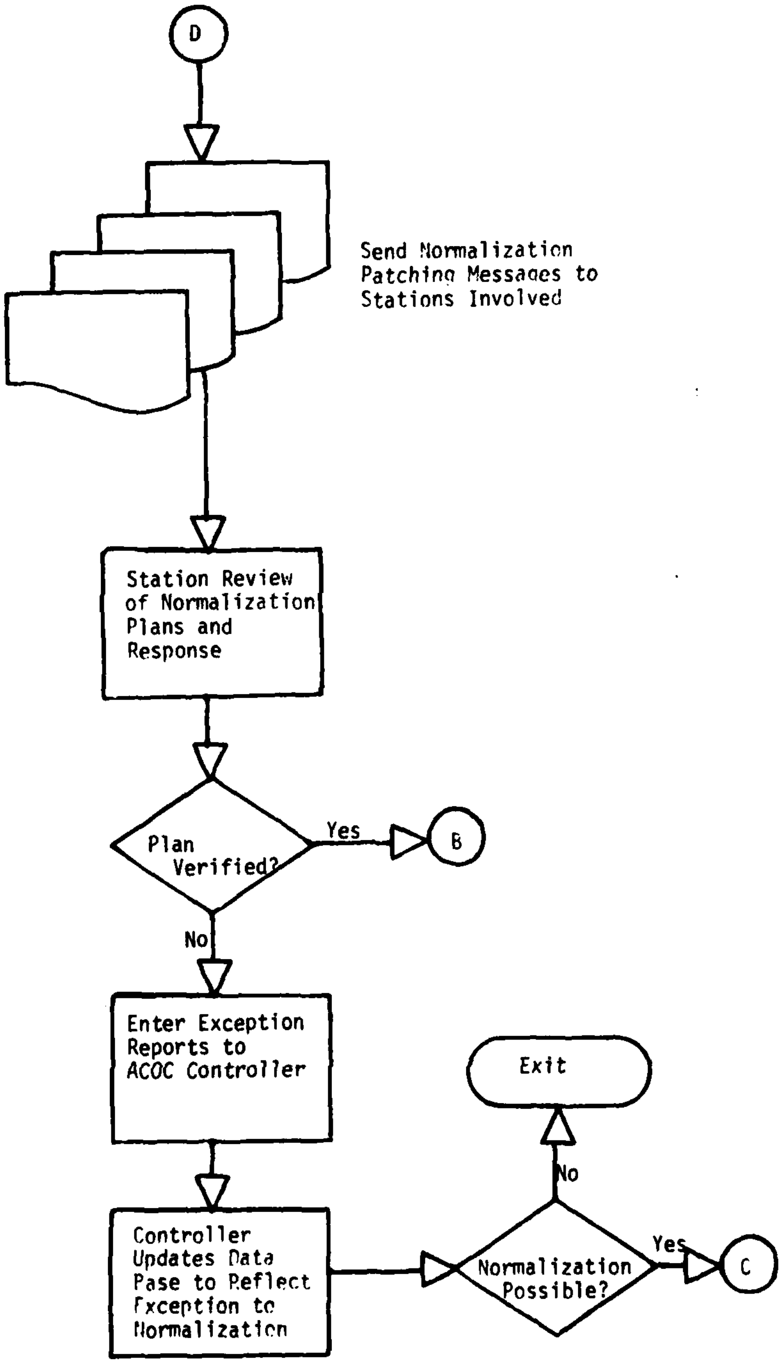


Figure 4-6. Normalization Activity (concluded)

ACOC for the area controller to correct his data base. If the area controller still sees the possibility of normalization, the normalization routine is run again to generate a new plan for station submission. Once all stations have accepted the normalization plan, the area controller can respond by allowing all patches to be made and data base updates to be finally implemented to show the route normalization.

4.3.2 The Altroute Message Formats

4.3.2.1 Fault Status Reports--Figure 4-7 presents a fault report format for messages sent up the ATEC hierarchy. This format follows the one presented in Report 2 (p. 5-39). From this type of report message, the fault file entries and links of the ACOC data base could be generated and the fault made visible in the connectivity data base.

4.3.2.2 Altroute Patching Message Formats--Once an altroute has been synthesized by the algorithms, ACOC sends messages to the stations involved in the patching operation. The node and sector to which these instructions are sent act only as message relay points.

To develop the altroute message formats, a specific example is used (see Figure 4-8). This altroute was discussed in Report 3 as one of the response time scenarios (Section 2.8). In this example the circuit 6D23 (using the last four characters of CCSDs) has failed due to link M0063 failure. The circuit is altrouted by preempting the two circuits shown on the LKF to DON to FEL route. LKF must patch the main distribution frame (MDF) appearance of the circuit to a new channel bank port. FEL patches the altroute back into the original route. The station at DON preempts two circuits by patching C784 to WCCA. Station at RMN is not involved in the altrouting messages even though the altroute passes through it.

INITIAL FAULT REPORT:	Characters
ATEC message header	21
Message identifier*	2
Fault report number	4
Circuit, trunk or link ID	9
Submitting location	4
Terminating locations	8
Location of fault	4
Time out	8
Degree of degradation	3
Cause of fault (Computer generated message. Should define the service's segment that is effected by this failure)	20
ATEC message trailer	2
Total =	85

FOLLOW-UP FAULT REPORT:	
ATEC message header	21
Message identifier	2
Fault report number	4
Reference fault report number	4
Submitting location	4
Location of fault	4
Time of this report	8
Degree of degradation	3
ETR	4
Narrative field	57
ATEC message trailer	2
Total =	103

*Identifies the message for display format processing.

Figure 4-7. Format of the Fault Status Reports

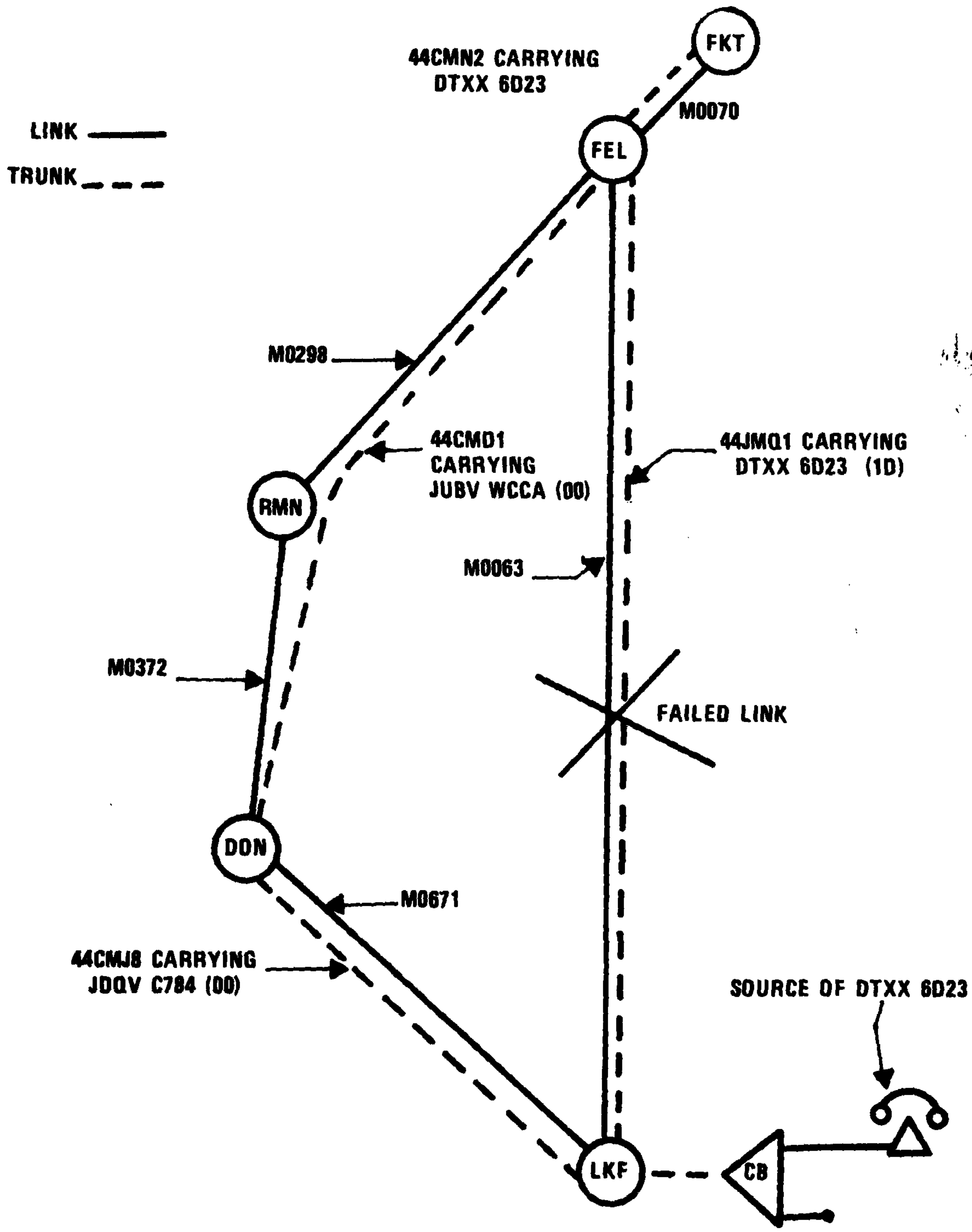


Figure 4-8. Example of a Circuit Altroute Patch

To develop the patching message formats for the stations, first design a station display that will give the tech controller the information needed for the patching. The area controller will also have a display to review the altroute. Starting with the area display will facilitate designing the station display by making one a subset of the other.

Figure 4-9 shows the area controller's altroute patching summary display. The first line is not a patch, but actually lists the circuit being altrouted. The stations given as "to" and "from" indicate the stations between which the altroute must exist in order to restore service. The fields following the station names (LKF and FEL) indicate the link, supergroup, group, and channel used to enter these stations from the segment of the normal route that is now failed. The remaining lines give actual patches to establish the altroute. The preempted circuit CCSD is first listed along with its RP for reference to the controllers. The station making the listed patch along with the status of the patch message to that station is given next. Finally, the actual patch is given. The two station entries give the stations connected by the patch being made at the patching station. The link, supergroup, and channel data for the patch refers to the appearance of the preempted circuit at the patching station.

We chose to use link, supergroup, group, and channel data to identify the patch rather than a channel on a trunk. Names of trunks may change on a transmission link, but the transmission system multiplex names always remain the same during service changes.

SUMMARY ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPTED CCSD	PATCH STATION	RP	FROM	TO
-/010	DTXX 6D23		1D	LKF/M0063/A310	FEL/M0063/A301
-/011	JDQV C784	LKF(TEMP) †		LKF/MDF (6D23)	DON/M0671/A410
-/012	JDQV C784	DON(REJ) †	00	LKF/M0671/A410	FEL/M0372/B120
	JUBV WCCA		00		
-/013	JUBV WCCA	FEL(ACC) †	00	LKF/M0298/A410	FEL/M0070/B120

COMMAND ( ) Enter a command to enter data base update mode (DB), algorithm parameter modification and re-run (RR), drop altroute (DA), finally implement altroute patching (FI) or edit station exception reports (ER).

SEND MESSAGE ( )

† (TEMP = temporary
REJ = rejected
ACC = accepted)

Figure 4-9. Area Altroute Patching Display

The display contains two operator entry fields. The "SEND MESSAGES" field automatically sends the patching messages to the appropriate patching stations. The messages will then enter a "TEMP" status mode indicating that the altroute is only temporarily made. The patching stations have the plan and are evaluating it. The stations will then send their response to the area controller and these will appear in the patching station status field next to each station's name. If all stations accept the plan, the operator can enter a command into the "COMMAND" field to send final implement messages to stations and update the data bases. If rejections occur, the stations will send exception reports. The area controller may act on suggestions of these exception reports to make data base changes or change parameters in the algorithm and then re-run the altroute search. He may also decide to drop the altroute job altogether. All these commands can be entered into the field of his display to complete the altroute control activity.

The PATCH ID/LINE can be used to uniquely identify a message sent from any station. Each altroute is assigned a new two digit sequence making up the first two numbers in the LINE. The last digit identifies a specific patch command per that altroute. A three-character ID field (see Figures 4-10, 4-11, and 4-12) gives a station identification to a line. Responses from the stations using both the station ID and LINE identifiers will give the area controller full knowledge of the station responding and the item on a particular altroute in question.

Figure 4-11 shows a message sent to a patching station which is also a terminal station of the altrouted circuit. Note that this and other station displays are exact subsets of the area display. The first line identifies the altrouted circuit. The actual patch appears in the second line. Note

ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPTED CCSD	RP	FROM	TO
*LKF/010	6D23	1D	LKF/M0063/A301	FEL
LKF/011	JDQV C784	00	LKF/MDF (6D23)	DON/M0671/A410

MESSAGE STATUS: (TEMP)

ALTROUTE ACCEPTABLE? ( )

EXCEPTIONS: Enter up to 80 characters to describe exception.
( )

SEND RESPONSE: ( )

Figure 4-10. Langerkopf Patching Display

ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPTED CCSD	RP	FROM	TO
*DON/011	6D23	1D	LKF	FEL
DON/012	JDQV C784 JUBV WCCA	00 00	LKF/M0671/A410	FEL/M0372/B120

MESSAGE STATUS: (TEMP)

ALTROUTE ACCEPTABLE? ( )

EXCEPTIONS: Enter up to 80 characters to describe exception.
( )

SEND RESPONSE: ( )

Figure 4-11. Donnersberg Patching Display

ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPTED CCSD	RP	FROM	TO
*FEL/010	6D23	ID	LKF	FEL/M0063/A301
FEL/013	JUBV WCCA	00	DON/M0298/A824	FKT/M0070/A301

MESSAGE STATUS: (TEMP)

ALTROUTE ACCEPTABLE? ( )

EXCEPTIONS: Enter up to 80 characters to describe exception.
( )

SEND RESPONSE: ( )

Figure 4-12. Feldberg Patching Display

that MDF refers to the main distribution frame at this circuit drop station. The other "TO" patch gives the multiplex identification of a trunk to DON to which the MDF is to be patched for the altroute. The message status field is an output field to tell the tech controller when to actually implement the patch. In "TEMP" mode, the controller knows that the area controller has just sent out the plan and is awaiting station responses to it. When all stations finally agree on a plan, the message status changes to "VERIFIED" to indicate that the altroute patch should now actually be made. A message indicating the response of the station to ACOC is entered into "ALTROUTE ACCEPTABLE" with an exception message if rejected. The "SEND RESPONSE" sends the answers automatically to ACOC.

Figures 4-11 and 4-12 show other examples of messages to patching stations. Station DON is a new station along the circuit's route and patches onto two preempted circuits. FEL was the station where re-entry to the normal route was found to be possible and gives as its "TO" patch the first trunk along the original route that attaches to the altroute.

Figure 4-13 finally gives a format and sizing of the altroute patching message. Only variable data is sent. The field sizes for the display will decompose the character string into the data items and provide the display delimiters. The ATEC format is used and only one block is needed per station per altroute. The field identifying the message type is used by the message processor to interpret the string of raw characters in the message field and set up the proper display for the controller. Two characters assumed here allow for a number of message types to be formatted for display.

	Characters
ATEC message header	21
Message identifier *	2
Display line 1--Altrouted circuit	27
Display line 2--Patch	50
ATEC message trailer	2
Total =	100

*Identifies this as a patching message in order to set up the proper display formats and indicates message status to the controller.

Figure 4-13. The Patching Message Format for Circuits

The patching messages for trunk altrouting are demonstrated with the example of Figure 4-14. The displays are shown in Figures 4-15, 4-16, 4-17 and 4-18. These displays are logical extensions of the circuit patching messages and are not discussed in detail here. The message format and sizing is given in Figure 4-19.

4.3.2.3 Normalization Patching Messages--Following the method for establishing the altroute patching messages, normalization messages will be derived by working an example. Figure 4-20 shows the normalization patching for the circuit altroute example given earlier. The area controller would be given the display of Figure 4-21 from the normalization routine to allow him to review the plan. The patching format follows the altroute patching format in order to use the controller's familiarity with the altroute display. The first line gives the circuit whose altroute is being removed and whose normal route is being restored. The following lines give the patches needed to establish the normal route and re-connect the preempted circuits used to establish the altroute. Each station has two patch items to carry out these actions. The line labelling, message status, and response field are the same in function and format as described earlier for the altroute patching displays.

Figures 4-22, 4-23 and 4-24 show station displays for patching as subsets of the area display. The first line again denotes the circuit whose route is being normalized. The response fields here are also duplicates of the altroute displays and work in the same manner.

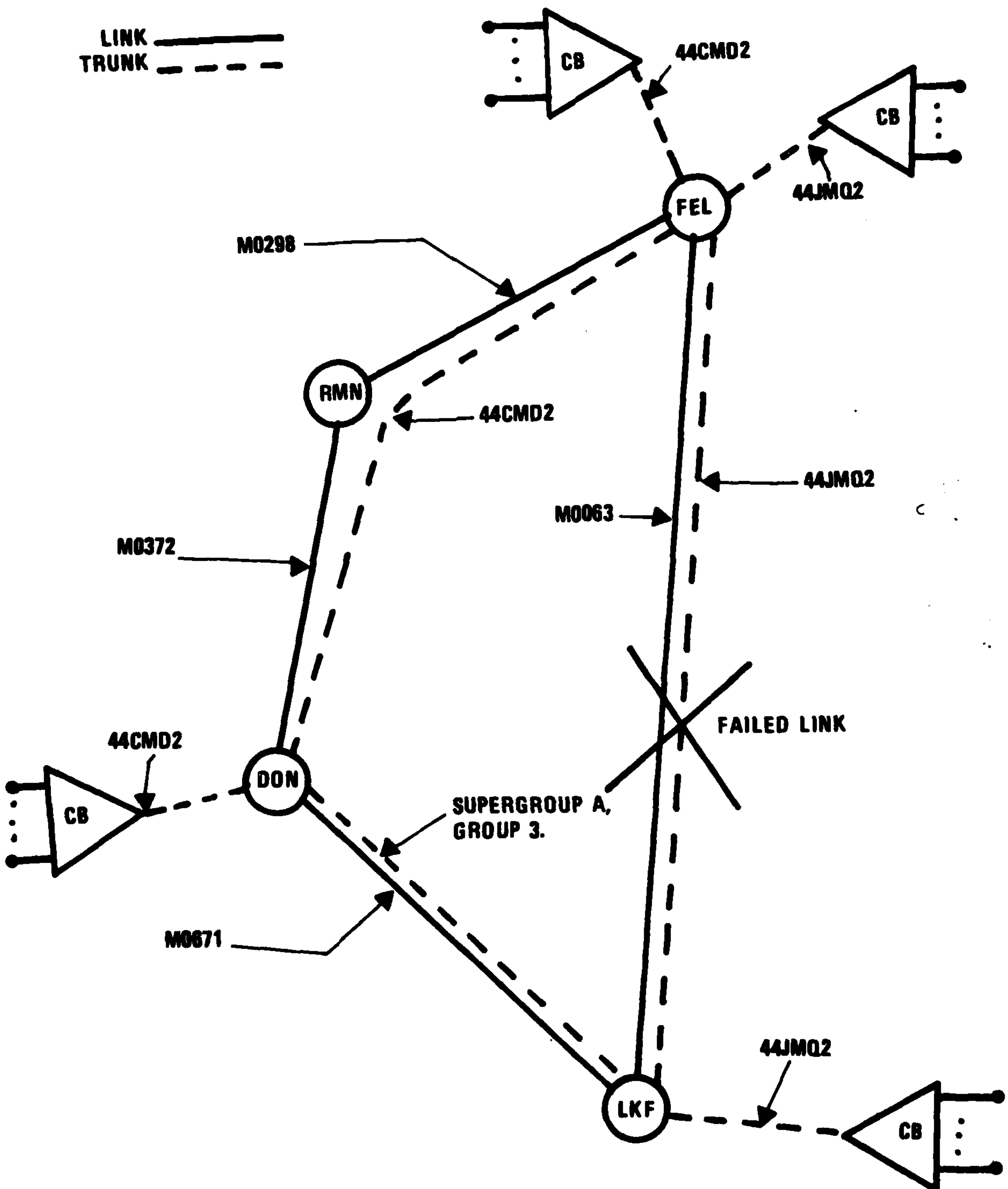


Figure 4-14. Example of a Trunk Altroute

SUMMARY ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPT	PATCH STATION	RP	FROM	TO
*/010	44JMQ2		lowest 2A	LKF/M0063/A1	FEL/M0063/A1
-/011	spare	LKF(TEMP)	none	LKF/CB(44JMQ2)	DON/M0671/A3
-/012	44CMD2	DON(ACC)	highest 3B	LKF/M0671/43	FEL/M0372/A4
-/013	44CMD2	FEL(REJ)	highest 3B	DON/M0298/B1	FEL/CB(44JMQ2)

EXCEPTIONS: ( ) Enter command to enter update data base (DB), algorithms parameter modification and re-run mode (RR), drop the altroute action (DR), finally implement altroute (FI) or edit station exception reports (ER).

SEND MESSAGES: ( )

Figure 4-15. Area Altroute Message Summary Display

ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPT	RP	FROM	TO
*LKF/010	44JMQ2	lowest 2A	LKF/M0063/A1	FEL
LKF/011	spare	none	LKF/CB(44JMQ2)	DON/M0671/A3

MESSAGE STATUS: (TEMP)

ALTROUTE ACCEPTABLE? ( )

EXCEPTIONS: Enter up to 80 characters to describe exception.
( )

SEND RESPONSE: ( )

Figure 4-16. Langerkopf Patching Display

ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPT	RP	FROM	TO
*DON/010	44MMQ2	lowest 2A	LKF	FEL
DON/012	44CMD2	highest 3B	LKF/M0671/A3	FEL/M0372/A4

MESSAGE STATUS: (TEMP)

ALTROUTE ACCEPTABLE? ( )

EXCEPTIONS: Enter up to 80 characters to describe exception.
( )

SEND RESPONSE: ( )

Figure 4-17. Donnersberg Patching Display

ALTROUTE PATCHING INSTRUCTIONS

PATCH ID/LINE	PREEMPT	RP	FROM	TO
*FEL/010	44MMQ2	lowest 2A	LKF	FEL/M0063/A1
FEL/013	44CMD2	highest	DON/M0298/B1	FEL/CB(44JMQ2)

MESSAGE STATUS: (TEMP)

ALTROUTE ACCEPTABLE? ( )

EXCEPTIONS: Enter up to 80 characters to describe exception.
( )

SEND RESPONSE: ( )

Figure 4-18. Feldberg Patching Display

	Characters
ATEC message header	21
Message identifier*	2
Display line 1--altroute trunk	27
Display line 2--Patch	34
ATEC message trailer	2
Total=	86

*Identifies the message type for display format generation and message status state.

Figure 4-19. Patching Message Format for Trunks

The route normalization displays for trunk normalization are given in an example in Figure 4-25. The displays resulting from that example which define the message content are found in Figures 4-26, 4-27, 4-28 and 4-29. These displays are direct extentions of the circuit normalization displays described earlier.

Finally, the message formats and sizes for these normalization patch messages are given in Figure 4-30 for both the circuit and trunk cases.

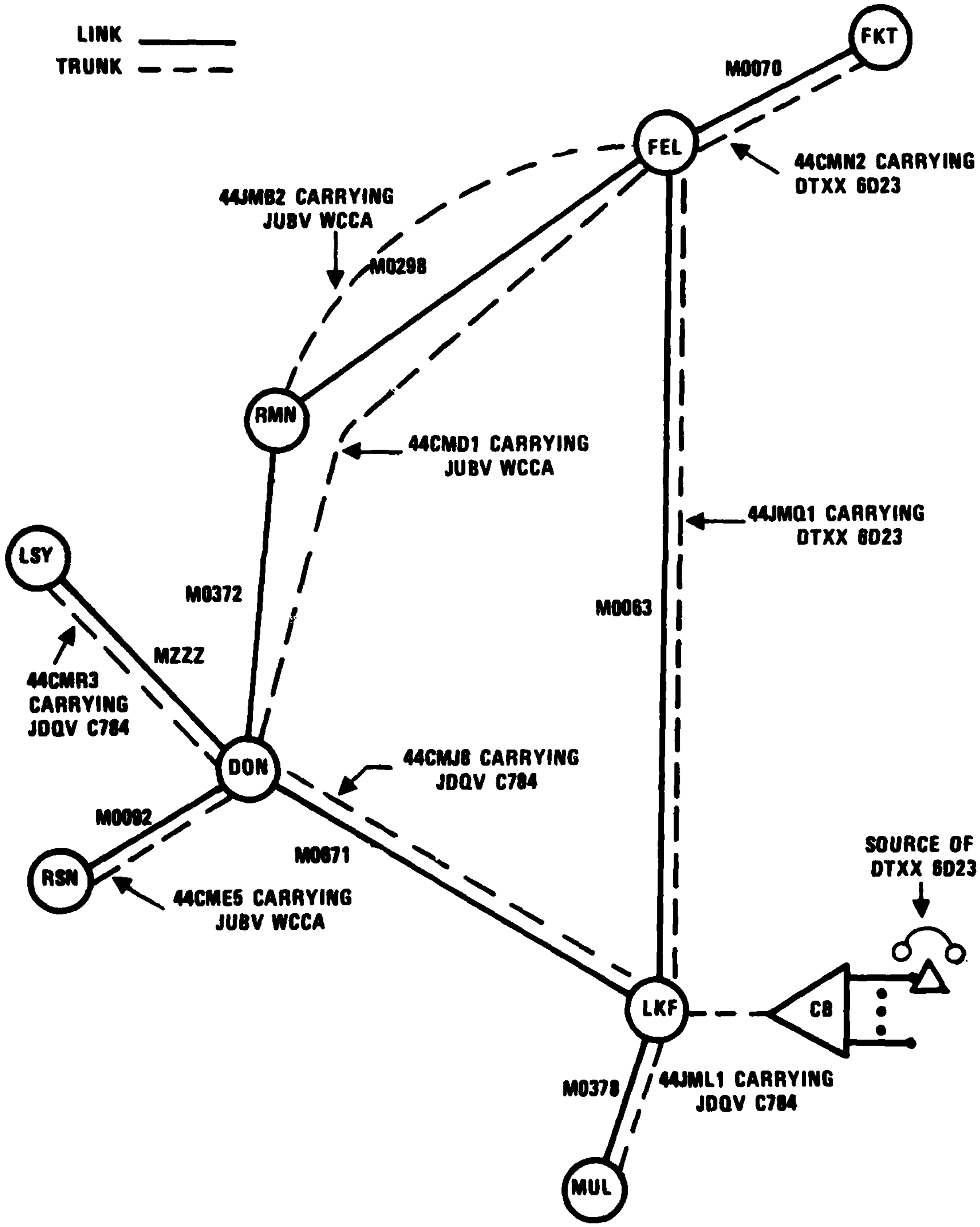


Figure 4-20. Circuit Normalization Example

SUMMARY NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	CIRCUIT	PATCH STATION AND STATION	FROM	TO
*-/010	DTXX 6D23		LKF/M0063/A301	FEL/M0063/A301
-/011	DTXX 6D23	LKF(TEMP)	LKF/MDF	FEL/M0063/A301
-/012	JDQV C784	LKF(TEMP)	MUL/M0378/A101	DON/M0671/A410
-/013	JDQV C784	DON(TEMP)	LKF/M0671/A410	LSY/MZZZZ/B222
-/014	JUBV WCCA	DON(TEMP)	RSN/M0092/A714	FEL/M0372/B120
-/015	DTXX 6D23	FEL(ACC)	DON/M0298/A824	RMN/M0298/B612
-/016	JUBV WCCA	FEL(ACC)	LKF/M0063/A301	FKT/M0070/A301

EXCEPTIONS: ( ) Enter command to enter data base update mode (DB), drop entire normalization plan (DR), finally implement normalization (FI) or edit station exception reports (ER).

SEND MESSAGES: ( )

Figure 4-21. Area Normalization Patching Summary Display

NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	CIRCUIT	FROM	TO
*LKF/010	DTXX 6D23	LKF/M0063/A301	FEL
LKF/011	DTXX 6D23	LKF/MDF(6D23)	FEL/M0063/A301
LKF/012	JDQV C784	MUL/M0378/A101	DPN/M0671/A410

MESSAGE STATUS: (TEMP)

NORMALIZATION ACCEPTABLE? ( )

EXCEPTIONS: Enter exceptions in less than 80 characters.
( )

SEND RESPONSE: ( )

Figure 4-22. Langerkopf Normalization Patching Display

NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	CIRCUIT	FROM	TO
*DON/010	DTXX 6D23	LKF	FEL
DON/013	JDQV C784	LKF/M0671/A410	LSY/MZZZZ/B222
DON/014	JUBV WCCA	RSN/M0092/A714	FEL/M0372/B120

MESSAGE STATUS: (TEMP)

NORMALIZATION ACCEPTABLE? ( )

EXCEPTIONS: Enter exceptions in less than 80 characters.
( )

SEND RESPONSE: ( )

Figure 4-23. Donnersberg Normalization Patching Display

NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	CIRCUIT	FROM	TO
*FEL/010	DTXX 6D23	LKF	FEL/M063/A301
FEL/015	DTXX 6D23	LKF/M0063/A301	FKT/M0070/A301
FEL/016	JUBV WCCA	DON/M0298/A824	RMN/M0298/B612

MESSAGE STATUS: (TEMP)

NORMALIZATION ACCEPTABLE? ( )

EXCEPTIONS: Enter exceptions in less than 80 characters.
( )

SEND RESPONSE: ( )

Figure 4-24. Feldberg Normalization Patching Display

4.4 SOFTWARE REQUIREMENTS FOR CONTROL IMPLEMENTATION

4.4.1 Software Requirements for Altrouting

4.4.1.1 Description of the Software--The description of additional software to implement the altrouting algorithms is presented in this section. A large part of the software required to support the altrouting control is described in Report 2 (Sections 4.1 and 4.2) where functional flows for data base updating and status reporting are laid out and sized. Functional flows of these tasks have been given and the software elements to perform these tasks are included in the software hierarchy.

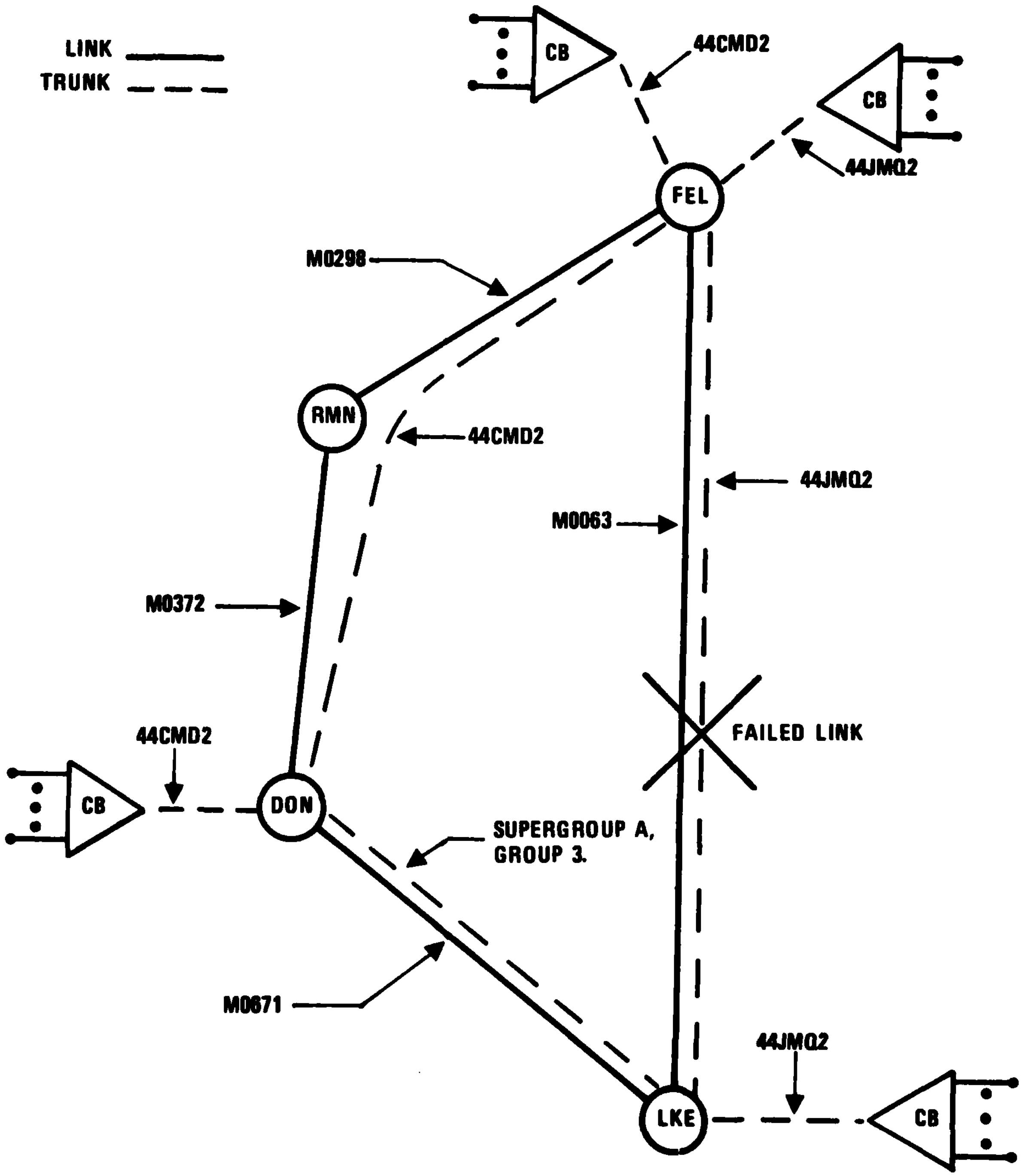


Figure 4-25. Example of a Trunk Route Normalization

SUMMARY NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	TRUNK	PATCH STATION	FROM	TO
*-/010	44JMQ2		LKF/M0063/A1	FEL/M0063/A1
-/011	44JMQ2	LKF(TEMP)	LKF/CB(44JMQ2)	FEL/M0063/A1
-/012	44CMD2	DON(ACC)	DON/CB(44CMD2)	FEL/M0372/A4
-/013	44JMQ2	FEL(REJ)	LKF/M0063/A1	FEL/CB(44JMQ2)
-/014	44CMD2	FEL(REJ)	DON/M0298/B1	FEL/CB(44CMDQ2)

EXCEPTIONS: ( ) Enter command to enter data base update mode (DB), drop entire normalization plan (DR), finally implement normalization plan (FI) or edit station exception reports (ER).

SEND MESSAGES: ( )

Figure 4-26. Area Route Normalization Patching Summary Display

NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	TRUNK	FROM	TO
*LKF/010	44JMQ2	LKF/M0063/A1	FEL
LKF/011	44JMQ2	LKF/CB(44JMQ2)	FEL/M0063/A1

MESSAGE STATUS: (TEMP)

NORMALIZATION ACCEPTABLE? ( )

EXCEPTIONS: Enter exceptions in less than 80 characters.
( )

SEND RESPONSE: ( )

Figure 4-27. Langerkopf Route Normalization Patching Display

NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	TRUNK	FROM	TO
*DON/010	44JMQ2	LKF	FEL
DON/012	44CMD2	DON/CB(44CMD2)	FEL/M0372/A4

MESSAGE STATUS: (TEMP)

NORMALIZATION ACCEPTABLE? ( )

EXCEPTIONS: Enter exceptions in less than 80 characters.
( )

SEND RESPONSE: ( )

Figure 4-28. Donnersberg Route Normalization Patching Display

NORMALIZATION PATCHING INSTRUCTIONS

PATCH ID/LINE	TRUNK	FROM	TO
*FEL/010	44JMQ2	LKF	FEL/M0063/A1
FEL/013	44JMQ2	LKF/M0063/A1	FEL/CB(44JMQ2)
FEL/014	44CMD2	DON/M0298/B1	FEL/CB(44CMD2)

MESSAGE STATUS: ( )

NORMALIZATION ACCEPTABLE? ( )

EXCEPTIONS: Enter exceptions in less than 80 characters.
( )

SEND RESPONSE: ( )

Figure 4-29. Feldberg Route Normalization Patching Display

The altrouting control function is defined in terms of the functional flow method of Report 2. From such a description, additional software elements are defined and sized and can be entered into the overall software hierarchy (see Figure 4-31). The flow chart representation of the altrouting control activity in Figure 4-6 will guide this functional flow generation.

Figures 4-32 and 4-33 show functional flows for key altroute implementation activities that have not already been analyzed in Report 2. The flow format of Report 2 was used in the analysis. The functional sub-elements in the control action hierarchy are seen in Figure 4-32. This is essentially the hierarchy of Report 2 with several additions regarding the altrouting control and normal routing normalization action (to be discussed later). The third

CIRCUIT NORMALIZATION	Characters
ATEC message header	21
Message type identifier	2
Display line 1--Circuit restored to normal routing	29
Display line 2--Normalization 1	38
ATEC message trailer	2
ATEC message header	21
Display line 3--Normalization 2	38
ATEC message trailer	2
Total =	153

TRUNK NORMALIZATION	
ATEC message header	21
Message type identifier	2
Display line 1--Trunk restored to normal routing	25
Display line 2--Normalization 1	22
Display line 3--Normalization 2	22
ATEC message trailer	2
Total =	94

Figure 4-30. Route Normalization Patching Messages

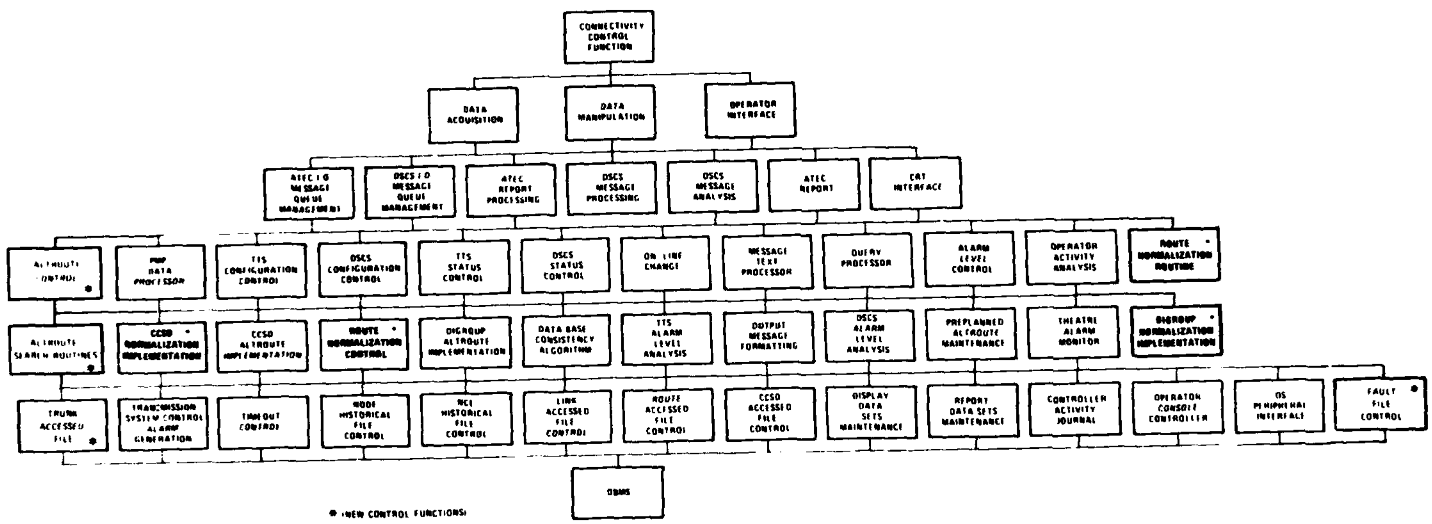


Figure 4-31. Network Connectivity Control Function Hierarchy Chart

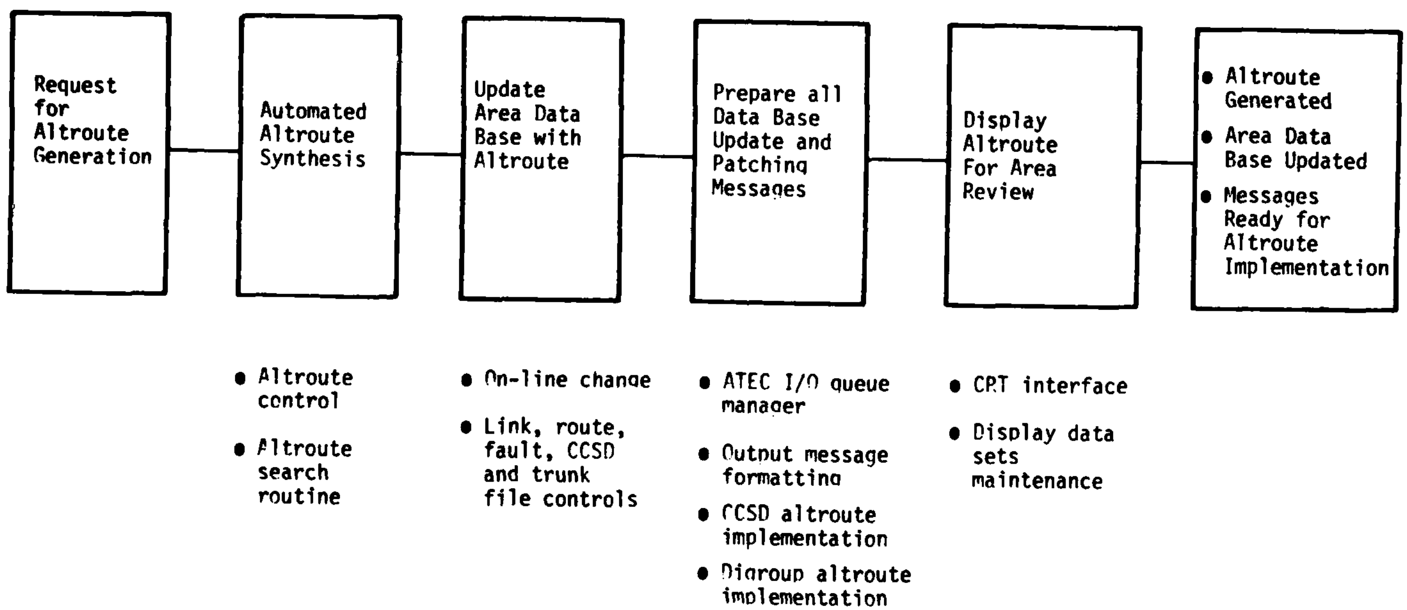


Figure 4-32. Connectivity Control--Altroute Generation

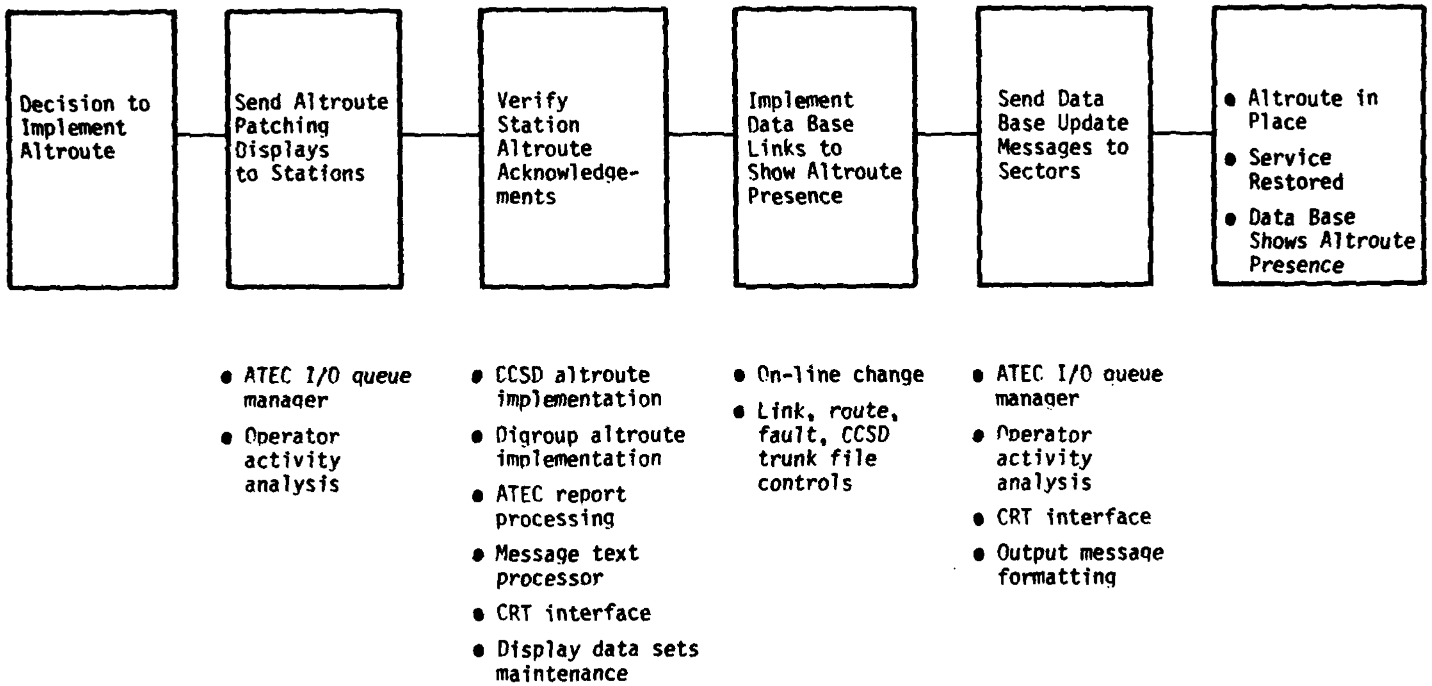


Figure 4-33. Connectivity Control--Altroute Implementation

level control actions added basically represent the altroute main calling routing (as altroute control) and a normalization routine interface (as route normalization control). These control levels interface ATEC reporting to determine the altroute work load due to reported failures and normalization load for reported repairs and fault file deletions. The actual altroute search package appears in the fourth or algorithm level as does the normalization routine. The access to trunks and fault files is finally entered into the fifth or data base interface level to permit full data base access and manipulation for the algorithms.

4.4.1.2 Software Sizing/Cost--The software required to implement the automatic altroute algorithms has been sized in a manner similar to the previous software sizing task reported in Report 2. Each software module has been sized in terms of estimated lines of HOL code required to implement the functions. Program occupancy is based on a ratio of 15 bytes of storage for each HOL instruction. Table 4-10 summarizes the software sizing for altroute implementation according to the modules defined in the software hierarchy chart. The individual routines that make up the altrouting functions have been individually sized and are included in Appendix C. The altroute control module includes the main calling routines and the common file handling logic. The altroute search module includes the circuit and trunk altrouting routines, the cost calculating routines, the circuit matching routine, and the goal station definition routine. The implementation modules are revised estimates from the previous sizing tasks, and the two file control modules are new modules required to support the algorithm. The 3490 lines of code translate to a cost of 582 man days of labor.

TABLE 4-10. SOFTWARE SIZING FOR ALTROUTE IMPLEMENTATION

Program Functional Module	Number Instructions HOL	Program Occupancy (Bytes)	Support Overlay	Functional Overlay
Altroute control	1250	18750		X
Altroute search routine	1540	23100		X
CCSD altroute implementation	200	3000		X
Digroup altroute implementation	200	3000		X
Fault file control	150	2250	X	
Trunk access file control	150	2250	X	
TOTALS	3490		4500	47850

4.4.2 Software for Route Normalization

4.4.2.1 Description of the Software--The control functional flow for the normalization of routing is described here in terms of the control actions from Figure 4-6. The normalization activity requires some new control actions in Figure 4-6. The "Route Normalization Routine" is the normalization algorithm described in Report 3. The "Route Normalization Control" function must interface the ATEC reporting activity to key into fault file removal due to equipment repairs. The notification of this action should result in the normalization routines being called into action.

The new control actions "CCSD Normalization Implementation" and "Digroup Normalization Implementation" act to generate displays, send messages and coordinate responses to messages involved in normalization patch coordination with stations.

Since status reporting has already been described in the functional flow of Report 2, the support for normalization data base updates has already been addressed there. The remaining normalization control activities are shown in functional flow form in Figures 4-34 and 4-35. These activities follow from the flow chart of Figure 4-6 and are similar to the altroute flows.

4.4.2.2 Software Sizing/Cost--The software required for normalization of normal routing after an altroute has been implemented has been sized and is summarized in Table 4-11. The routine associated with route normalization has been estimated in more detail in Appendix C. The 1010 lines of code required to implement these functions translates to 152 man days of labor. This cost increment is added to the total software effort required to implement the ACOC-WWOL system control processor.

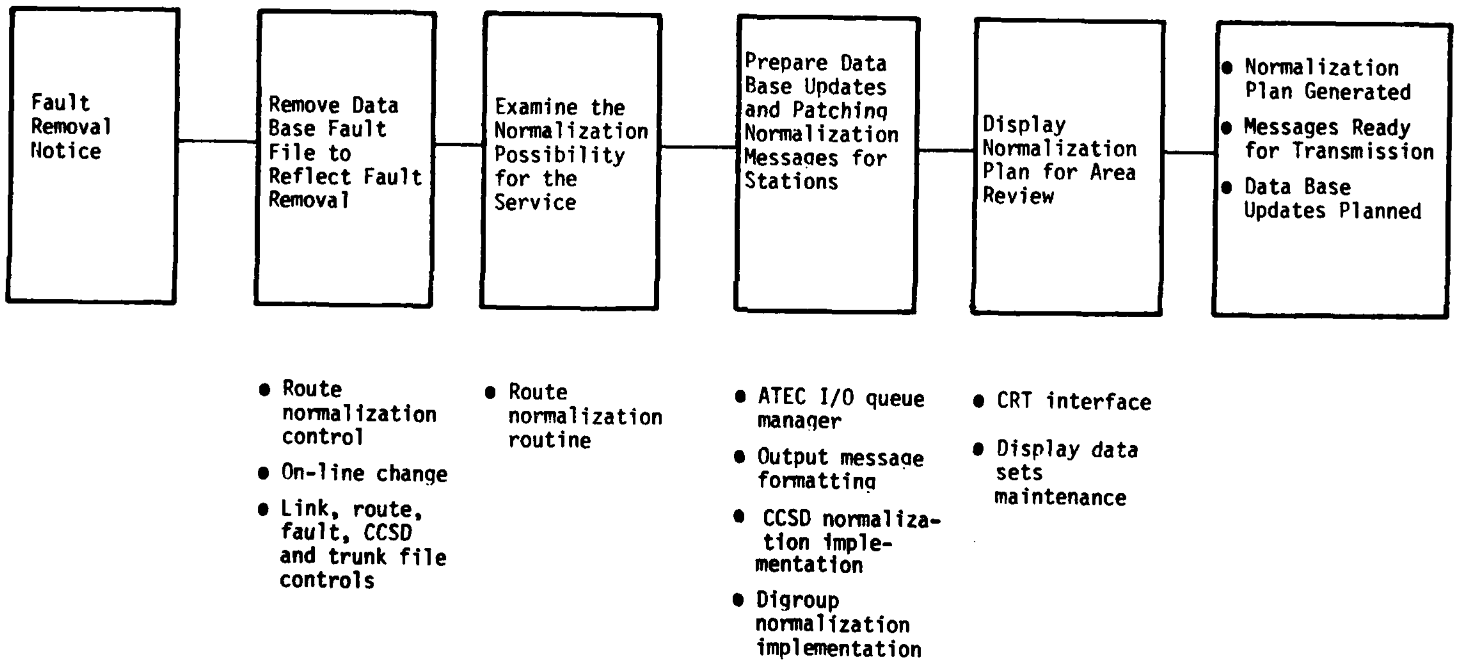


Figure 4-34. Connectivity Control--Normalization Plan Generation

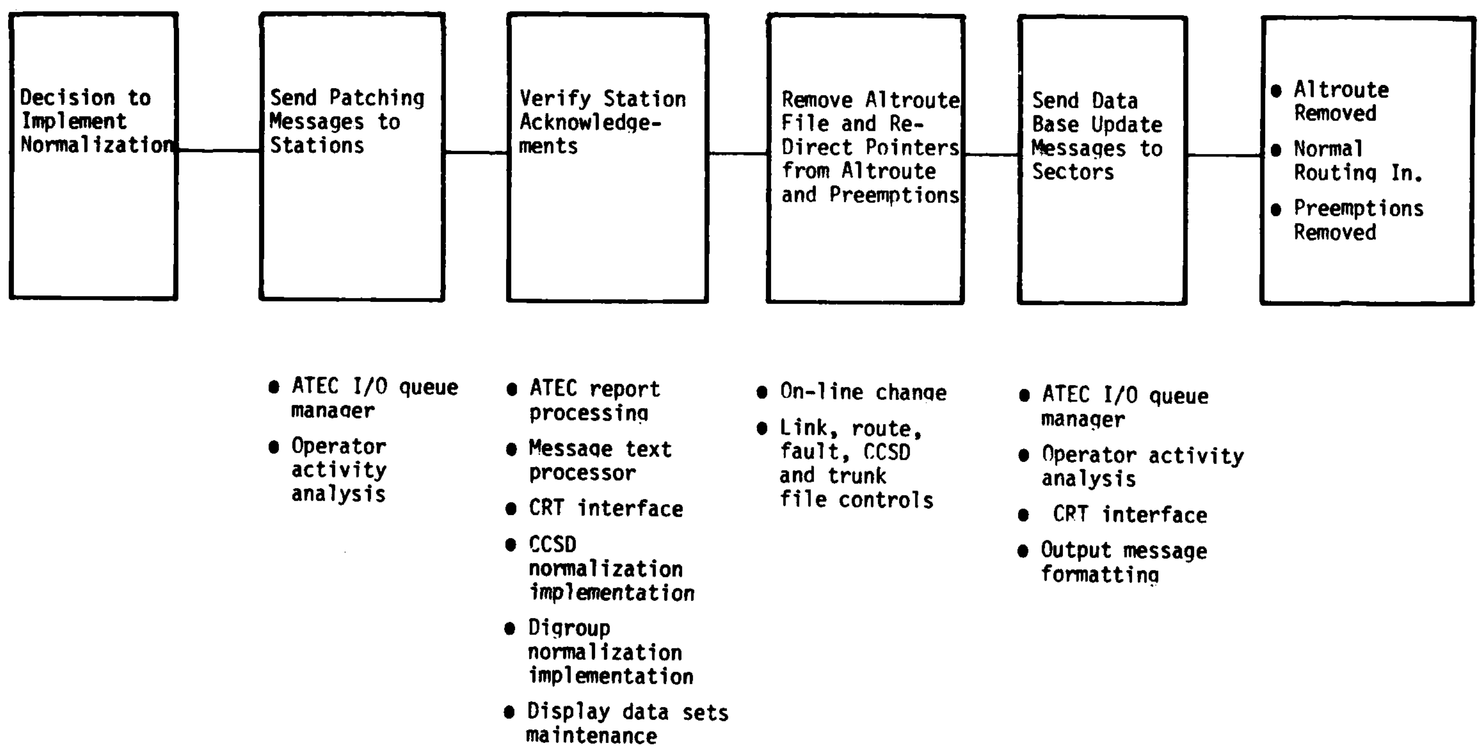


Figure 4-35. Connectivity Control--Normalization Plan Implementation

TABLE 4-11. SOFTWARE SIZING FOR NORMALIZATION IMPLEMENTATION

Program Functional Module	Number Instructions HOL	Program Occupancy (Bytes)	Support Overlay	Functional Overlay
Route normalization control	85	1275		X
Route normalization routines	425	6375		X
CCSD normalization implementation	300	4500		X
Digroup normalization implementation	200	3000		X
TOTALS	1010		0	15150

4.4.3 Software Requirements for AUTOVON Control Implementation

4.4.3.1 Software Description--The software needed to implement the recommended AUTOVON controls consists of a set of routines supporting automatic and manual changes to switch routing tables. Manual modification of routing tables is supported by an interactive CRT display process. The operator can call up the routing tables for any switch; and by positioning the cursor at any given entry and typing in a new entry, the routing is modified. The software at ACOC therefore accepts cursor and key commands when the routing table display is up. These commands are interpreted as routing modifications and a routing table change message is sent to the switch RAMM via ATEC. Software in the RAMM accepts the command input and appropriately modifies the switch memory.

Automatic control software is similarly straight-forward. There are basically two automatic routing algorithms: the adaptive routing algorithm and the primary-only routing algorithm. The adaptive routing algorithm is executed any time a trunk group failure is detected.

The adaptive routing algorithm operates in a special section of the data base which has the following data for each source destination pair of switches:

- A prioritized list of alternate routes. This list will have at least one route using each trunk group exiting the source, and one route using each trunk group entering the destination switch, so that there will be an operational route on the list as long as the switch is not isolated.

- The status of each alternate--failed, active, primary-only, active, standby.
- A code conversion indicator, for those routes where code conversion is required to prevent ring-around-the rosey.

This data base is engineered on a long-term basis and is subject to changes as a result of new facilities on changing traffic patterns.

When a trunk group fails, the software searches through the data base to find each route riding the failed trunk group. For each route found, the next alternate on the list is checked to see if it is redundant with a currently active route. For example, a section of the list for LKF-SCH would be as follows:

LKF-SCH

LKF-FEL-SCH

LKF-DON-SCH

LKF-HIN-FEL-SCH

In normal operation, the first three routes are active for this source destination pair. If the direct route failed, the adaptive routing algorithm would examine the LKF-HIN-FEL-SCH route and see that it is redundant with the LKF-FEL-SCH route. When the next alternate is found to be redundant, as was the case here, that alternate is not activated; and the next member of the list is examined.

In the case of LKF-SCH with the direct route failed, all other members of the list will be redundant since there are only three trunk groups to SCH and all three are in either active routes or failed. In this situation, the source destination pair will be left with only two routes. However, if the LKF-FEL trunk group had failed, it could be replaced by the LKF-HIN-FEL-SCH route.

When the routine finds failed routes or new routes to activate, it forms messages to the affected switch RAMMs to modify their routing tables. This keeps the switch from wasting time on failed routes and continually provides the best routing alternatives. A pre-engineered list was chosen instead of a search procedure for AUTOVON for the following reasons:

- The number of alternatives for routing is quite limited.
- There may be traffic-related reasons why roundabout routes may be given higher priority than more direct routes.
- The list process needs only minimal trunk group status data to make its decisions.
- Traffic studies have shown that real-time selections of routes based on instantaneous traffic measurements do not provide better service than pre-engineered routes.

Therefore, this algorithm provides near optimum service with minimum information sensing and processing.

The second major automatic control algorithm is the primary-routing-only algorithm. This algorithm starts with a special measurement by the RAMM. Every five minutes, the RAMM accumulates the percent of the time that

the all trunks busy lead is active for each group and makes a threshold decision when the trunk is heavily loaded. Typical threshold values would be 80% to 90% of the time. When the threshold measurement is taken, a message is sent to ACOC containing the busy/no busy decision for the trunk groups.

The software at ACOC searches its data base of routing tables to find all non-primary routes which ride each trunk group marked busy. It then sends messages to the originating switches of these routes to deactivate the routes. Similarly, the algorithm searches for secondary and tertiary routes which had been temporarily deactivated because of a busy trunk which had become not busy during the previous measurement interval. These routes are reactivated via messages to the switches.

Routes which are temporarily deactivated because of traffic loading are not replaced by the adaptive routing algorithm since they will be reactivated as soon as the traffic decreases. They are known to be non-primary under an operational primary route. If the primary route should happen to fail, the adaptive routing algorithm would make the secondary route a primary which would reactivate it regardless of the traffic situation.

A simpler alternative algorithm could be implemented at the switch itself without any telemetering of messages. Switches could detect and not use heavily loaded trunk groups for other than primary routed originating traffic. Since AUTOVON operates with originating office control, all tandem traffic appears to be primary routed, so simpler algorithms would not affect tandem traffic. Since the primary goal of this algorithm is to prevent multiple attempts on transatlantic routes during a traffic overload, thereby reducing

intra-European signalling traffic and switch processing loads, this simpler version of primary routing is not sufficient. The primary routing restriction needs to operate on tandem as well as originating traffic, thereby requiring the algorithm described here.

4.4.3.2 Software Sizing and Cost--The software modifications or additions to accomplish AUTOVON control and implementation are made to two subsystems, the RAMM and the ACOC-WWOLS system control processor. The recommended modifications to the RAMM software are listed in Table 4-12. A total of 955 FORTRAN and 230 assembly level instructions are required. Based on the assumptions made in Section 1.3.3, this translates to 178 man days of labor to make these modifications.

The increment of software added to the ACOC-WWOLS system control processor is the software to accommodate the two new algorithms described above. These two algorithms require an additional 400 lines of HOL code. This addition adds 67 man days of effort to the total system control processor tasks summarized in Section 1.3.3.

TABLE 4-12. RAMM SOFTWARE ADDITIONS/MODIFICATIONS

Program Module	Number of Instructions	Program (Bytes)
Obtain switch status parameters	25H	375
Build status message and queue	225H	3375
Obtain traffic parameter	25H	375
Processor traffic parameter for periodic transmission	75H	1125
Build traffic parameter message and queue	75H	1125
Operations KD command/message processor	175H	2625
ATEC port command/message processor	120H	1800
RAMM system software interface	150H	2250
ATEC message I/O driver	50H	750
KD message I/O driver	35H	525
Output message protocol handler	150A	450
Input message protocol handler	80A	240
TOTALS	955F/230A	15015

H = HOL (FORTRAN)

A = Assembly level

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GLOSSARY

ACAS	AUTOVON centralized alarm system
ACOC	Area communications operations center
ATEC	Automated technical control
ATOP	Automatic traffic overload protection
AUTODIN	Automatic data interchange network
AUTOVON	Automatic voice operated network
AUTOSEVOCOM	Automatic secure voice communication network
BCD	Binary coded decimal
BPS	Bits per second
CIS	Communications interface subsystem
CCO	Circuit control office
CCSD	Command circuit service designator
CONUS	Continental United States
CRT	Cathode ray tube
CRU	Channel reconfiguration unit
CS	Control segment
DCC	Destination code cancellation
DCS	Defense communications system
DEFCON	Defense condition
DSCS	Defense satellite communication system
DTMF	Dual tone multiple frequency
EIRP	Effective isotropic radiated power
ETR	Estimated time of repair
FDM	Frequency division multiplex
GOS	Grade of service
HOL	Higher order language

GLOSSARY (concluded)

IM	Inlet multiplexer
KDU	Keyboard display unit
LOS	Line of sight
MAS	Measurement acquisition subsystem
MDF	Main distribution frame
MF	Multiple frequency
MFT	Multiple frequency transceiver
NCC	Network control center
NCE	Network control element
NCS	Nodal control subsystem
OCE	Operational control element
OM	Outlet multiplexer
PSN	Packet switching node
RAMM	Rapid access maintenance monitor
RAN	Reassignment network
RP	Restoral precedence
RSJ	Register sender junctor
RSS	Received signal strength
SCS	Sector control subsystems
SCRAN	Subchannel reassignment network
SNCC	Subnetwork control center
TCE	Terminal control element
TDCS	Traffic data collection system
TRI-TAC	Tri-services tactical communication system
TTY	Teletype
VF	Voice frequency
WWOLS	World wide on-line system

APPENDIX A

EXAMPLES OF ALTROUTING ALGORITHM OPERATION

A.1 INTRODUCTION

This appendix will present some detailed altrouting examples using the altrouting algorithms developed in Report 3 of this study. The examples will use the European DCS configuration as of 1979. Specific failures will be assumed and the resulting altrouting job queue will be defined. Some of the circuit altroute groups and trunks in the queue will be altrouted and the details of the algorithm's steps outlined in the process. The purpose of these examples is to further clarify the altrouting algorithm's operation and to estimate the algorithm's run time for real altroutes.

A.2 ASSUMPTIONS

We will require several assumptions to be made in order that the problem is well defined from the algorithm's viewpoint. The assumptions of importance are:

DCS Connectivity

In order to use the data base available on network connectivity, the mid-1980's European DCS backbone model must be modified. Figure A-1 shows the backbone to be used as it was derived from current 1979 connectivity data. The main difference between this model and the 1980's deployment

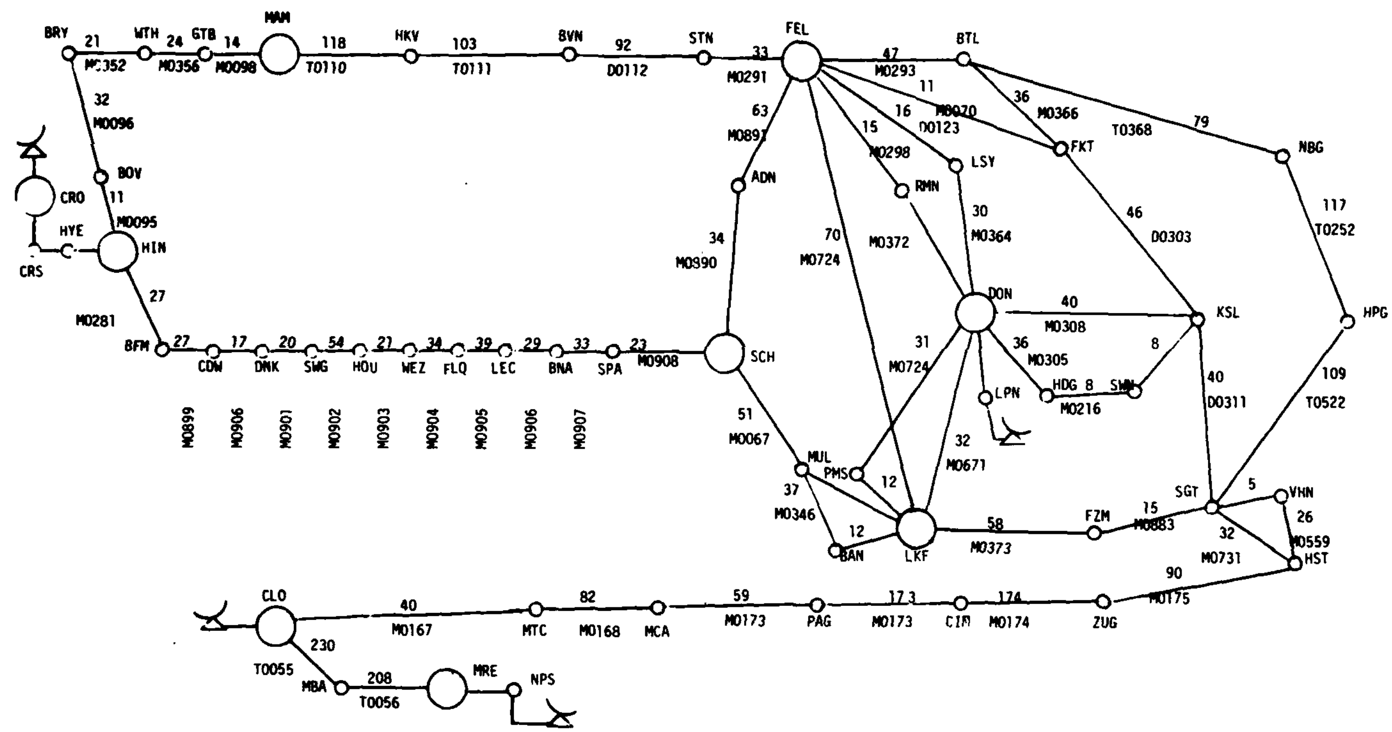

Figure A-1. Example Network Connectivity

INDEX TO SITE ABBREVIATIONS

ADN = Adenau, Ger.
ANS = Ansbach, Ger.
BAN = Bann, Ger.
BDH = Brandhof, Ger.
BFM = Botley Hill Farm, U.K.
BHR = Baumholder, Ger.
BNA = Ben Ahin, Bel.
BOV = Bovingdon, U.K.
BRY = Barkway, U.K.
BSN = Bonstetten, Ger.
BTL = Breitsol, Ger.
BUN = Bruggen, Ger.
CDW = Cold Blow, U.K.
CIM = Cima Gallina, IT.
CLO = Coltano, IT.
CRO = Croughton, U.K.
CRS = Christmas Common, U.K.
DNK = Dunkirk, U.K.
DON = Donnersberg, Ger.
FEL = Feldberg, Ger.
FKT = Frankfurt, Ger.
FLQ = Flobecq, Bel.
FZM = Friolzheim, Ger.
GTB = Great Bromley, U.K.
HDG = Heidelberg, Ger.
HDM = Heidenheim, Ger.
HIN = Hillingdon, U.K.
HKV = Hoek Van Holland, Neth.
HOU = Houtem, Bel.
HPG = Hohenpeissenberg, Ger.
HST = Hohenstadt, Ger.
HUM = Humosa, Sp.
HYE = High Wycombe, U.K.
KSL = Koenigstuhl, Ger.
LAG = Lago di Patria, IT.
LDN = Landstuhl, Ger.
LEC = Le Chenoi, Bel.
LEV = Levkas, Gr.
LKF = Langerkopf, Ger.
LSY = Lindsey, Ger.
MAM = Martlesham Heath, U.K.
MBA = Mt. Limbara, Sar.
MCA = Mt. Corna, IT.
MHN = Mannheim, Ger.
MRA = Martina Franca, IT.
MRE = Mt. Vergine, IT.
MTC = Mt. Cimone, IT.
MTS = Mt. Serra, IT.
MUL = Muhl, Ger.
NBG = Nuernberg, Ger.
NPS = Naples, IT.
PAG = Paganella, IT.
PMS = Pirmasens, Ger.
RMN = Rhein Main, Ger.
SCH = Schoenfeld, Ger.
SGT = Stuttgart, Ger.
SHW = Schwanberg, Ger.
SPA = Spa Malchamps, Bel.
STN = Stein, Ger.
STO = Stocksberg, Ger.
SWN = Schwetzingen, Ger.
VHN = Vaihingen, Ger.
WBG = Wurzberg, Ger.
WEZ = Westrozebeke, Ger.
WMS = Worms, Ger.
ZUG = Zugspitze, Aus.

Figure A-1. Example Network Connectivity (concluded)

model is the eastern Germany area--the outer path from Stuttgart to Breitsol has been modified, and Frankfurt now appears in the backbone on a key path from Breitsol to Koenigstuhl.

Patching Compatibility

The determination of whether a preempting circuit can patch into another circuit's channel depends upon the types of channels. The distinction between voice and TTY channels is clearly identified by the circuit type classification in the data base (Reference 8, DCAC 310-65-1, Section 7). Difference among TTY channels are the data rates which influence the modulation and phase equalization of the channel. Voice/TTY distinctions will be used to determine patching compatibility between channels when a preemption is made. We assume that the voice and TTY circuits will appear at equal level patch bays at the patching stations. This guarantees that signal level and signalling mode are consistent for patching once the voice/TTY and data rate compatibilities are determined.

Patching trunks onto spare groups or preempted trunks will be done at the group distribution frame. All frequency division multiplex (FDM) groups should be in the same channel multiplex frequency band at this patch bay to allow any patching combinations.

Altroute "Cost" Method

The desirability of an altroute in the altroute search algorithms of Report 3 was determined by assigning "costs" to each altroute segment selected.

AD-A080 768 HONEYWELL SYSTEMS AND RESEARCH CENTER MINNEAPOLIS MN F/G 17/2
SYSTEM CONTROL FOR THE TRANSITIONAL DCS.(U)
JUL 79 F C ANNAND, D E DOTY, R V KRZYZANOWSKI DCA100-78-C-0017
UNCLASSIFIED SBIE-AD-E100 329 NL

3 of 3
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END
DATE
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3-80
DDC

Those costs were selected as:

- Route mileage
- Number of patches
- RPs of preempted circuits
- Transmission link type and reliability

These examples will use the first three of these costs in selecting a desirable route. The transmission cost item is not evident without inputs from other sources. The "heuristic cost" for these examples will simply be the estimate of altroute mileage for the unknown altroute segment.

The calculation of route mileages can be made from the network model of Figure A-1. Figure A-1 lists route mileages for all links in the network. The estimate of the mileage of the unknown altroute segment is made per the algorithm of Report 3 (Section 2.6.4). The "paths" used in that algorithm are identified from Figure A-1 as any link or series of links which have two-link stations for all but the end stations. For example, the links M0305, M0216, and M0217 define a "path" in the context of the algorithm.

The patching cost is added to the other costs whenever a new preemption is made and patched to the altroute. To cost the preemption of a circuit with a particular RP, a numerical value was assigned to every RP class (see Figure A-2). The numerical assignments were made to increase exponentially. The reason for this scaling is to represent the unequivocal dominance of one RP over lower RPs.

RP	Preemption Cost	RP	Preemption Cost
1A	1000	2F	28
1B	720	2G	22
1C	520	2H	17
1D	370	2I	13
1E	270		
1F	190	3A	10
1G	140	3B	5
		3C	2
2A	100		
2B	77	4A	1
2C	60	4B	.3
2D	46		
2E	36	00	0

Figure A-2. Preemption Cost vs RP

Finally, the scale factors used to combine the costs are determined. The scale factors are chosen so that equally important costs weigh equally in the cost sum. Mileage will be the reference in these examples and carry a scale factor of one. The RP cost scale was selected to have scale factor one also; a route extension of 100 miles is worth avoiding preemption of a 2A circuit. The patching scale factor of 50 is selected to make 100 miles of route extension equal to adding two additional patching stations to a route. The cost is calculated by:

$$\text{COST} = (\text{route mileage}) + 50^{*}\ (\text{number of patches})$$
$$+\ (\text{sum of preempted circuit RPs})$$

A.2 EXAMPLE 1

The failure of the radio tower on link M0902 (Houtem to Swingate) occurs, and the ETR is found to be three hours. This duration of outage on the carried trunks means that altrouting must be attempted. The following trunks are now out of service:

34JMB1	Hillingdon--Langerkopf
34JMB2	Hillingdon--Langerkopf
34JMC1	Hillingdon--Schoenfeld
34JMC2	Hillingdon--Schoenfeld
34JMA1	Hillingdon--Feldberg
34JMA2	Hillingdon--Feldberg
34JMA3	Hillingdon--Feldberg
34JMA4	Hillingdon--Feldberg
34CZA1	Hillingdon--Vaihingen

The altroute search begins at the trunk level. The starting station for the search is Hillingdon because the path from Hillingdon to Swingate is identified as a dead end spur by the goal station definition routine (Report 3, Section 2.6.5). Likewise, the terminal station for the trunk searches is either Schoenfeld or Feldberg due to the dead end spur from Schoenfeld to Houtem. The search for preemptable groups to altroute the trunks fails in all cases at Martlesham Heath due to the absense of any spare groups or preemptable trunks. The trunks are decomposed into their circuits for circuit altrouting in groups with common altroute ends.

The circuits in the altroute group between Hillingdon and Langerkopf are identified in Table A-1. All circuits listed are voice circuits and also are full duplex. Altrouting this group of circuits is representative of circuit altrouting in the European theatre. The steps at each search station will be detailed in terms of disc accesses needed to read data, stations accessible, trunks used, preemptions made, and costs to the new stations. The actual CCSD matching of a particular preemptable circuit with an altroute group circuit is not given because it is not important to the understanding of the process. The matching of the circuits by RPs is given instead in order to demonstrate the preemption rule for circuit selection. The first step in the altroute search process is explained in great detail in order to make the process clear. The remaining steps are given in terms of brief summaries of the important search parameters at each station.

Altrouting the Hillingdon--Langerkopf Circuit Group

Step 1--The first search station is Hillingdon. It is labelled as CLOSED in its TREE file entry (recall that file TREE was defined in Report 3, Section 2.6.3, to store the station labels during the search). The reading of the station file for Hillingdon (HIN) identifies three links from it: M0281 to Botley Farm, M0095 to Bovington, and M0054 to High Wycombe. The link M0281 is temporarily set to failed in order to identify the dead end spur created by the M0092 link failure. It is useless to consider its trunks because they lead to a dead end where altrouting is concerned.

Step 1a--This step examines routes over M0095 from Hillingdon. The link file record for M0095 is read in order to find the stations accessible from Hillington and which trunks make that access. Six trunks are found which

TABLE A-1. HILLINGDON-LANGERKOPF CIRCUIT GROUP

Circuit	RP	FS	ITS
9ADA	1C	Hillingdon	Langerkopf
9ADN	1C	Hillingdon	Langerkopf
6E19	1C	Hillingdon	Langerkopf
6F86	1C	Hillingdon	Langerkopf
9HED	1D	Hillingdon	Langerkopf
DN50	1D	Hillingdon	Langerkopf
9HMS	1D	Hillingdon	Langerkopf
6F14	1D	Hillingdon	Langerkopf
6F15	1D	Hillingdon	Langerkopf
9ADB	1G	Hillingdon	Langerkopf
9ADC	1G	Hillingdon	Langerkopf
9GTN	1G	Hillingdon	Langerkopf
9ADP	1G	Hillingdon	Langerkopf
9ADG	1G	Hillingdon	Langerkopf
9ADR	1G	Hillingdon	Langerkopf
9ADS	1G	Hillingdon	Langerkopf
9ADT	1G	Hillingdon	Langerkopf
9HDM	1G	Hillingdon	Langerkopf
6E47	1G	Hillingdon	Langerkopf
9DQY	1G	Hillingdon	Langerkopf
W106	2C	Hillingdon	Langerkopf
WA8Z	2C	Hillingdon	Langerkopf
WEF9 (a)*	2E	Hillingdon	Langerkopf
WEF9 (b)*	2E	Hillingdon	Langerkopf
C606	2F	Hillingdon	Langerkopf
9HCC	2I	Hillingdon	Langerkopf
WB5C	3A	Hillingdon	Langerkopf
C674	3A	Hillingdon	Langerkopf

*Two different segments of a multi-point circuit.

access Martlesham Heath (MAM) from Hillingdon over link M0092. Two trunks access Croughton but neither is listed in the data base so this station access is not considered further. Station MAM is entered into TREE and labelled as OPEN.

Selection of preemptable circuits can begin once the six trunk files of the trunks from Hillingdon to Martlesham Heath are read. Table A-2 identifies the circuits preempted on those six trunks. The selection begins by preempting the lowest RP circuit on the six trunks by the highest RP circuit in the altroute group. The second lowest RP circuit on the six trunks is preempted by the second highest RP circuit in the altroute group and so on. The process ends when either all altroute group circuits are matched with a preemptable circuit or no preemption of a lower RP circuit can be made. The last circuit preempted and its matching altroute circuit will be nearly the same RP level if preemption ends prematurely.

The trunk columns in Table A-2 define the altroute group circuits which preempted a trunk's circuits at the RP listed in the left-hand RP column. Most circuits were altrouted by using 00 or spares, and only three circuits required higher RP preemptions. The entire altroute group could not be altrouted over this set of trunks to MAM because of a lack of low RP circuits. The next circuit needing a preemption is at the 2E level, and there are no preemptable circuits lower in RP than 2E on any of the trunks. The numbers in the parentheses indicate the totals of each RP level in the altroute group which were found to be altrouted to MAM over M0095.

To further explain the preemption situation, Figure A-3 shows the preempting in terms of a group capacity distribution as was used in Report 3 (Section 2.9) to explain the altroute probability analysis.

TABLE A-2. PREEMPTION SELECTIONS FOR STEP 1 a

RP	Altroute Group Distribution	Circuits Preempted by Trunk*					
		33JMA1	33JMA2	33JMA3	33JMA4	33JMA5	33JM15
1C	4 (4)+						
1D	5 (5)						
1G	11 (11)						
2C	2 (2)						
2F	1 (0)					2E*	
2I	1 (0)						
3A	2 (0)				2C	2E	
00 and spare		2, 1G	3, 1D 3, 1G		2C	4, 1C 2, 1D	6, 1G

*Identifies the fact that a 2F circuit on trunk 33JMA5 was preempted by a 2E circuit in the altroute group.

+Number of circuits in the altroute group for which preemptions were found.

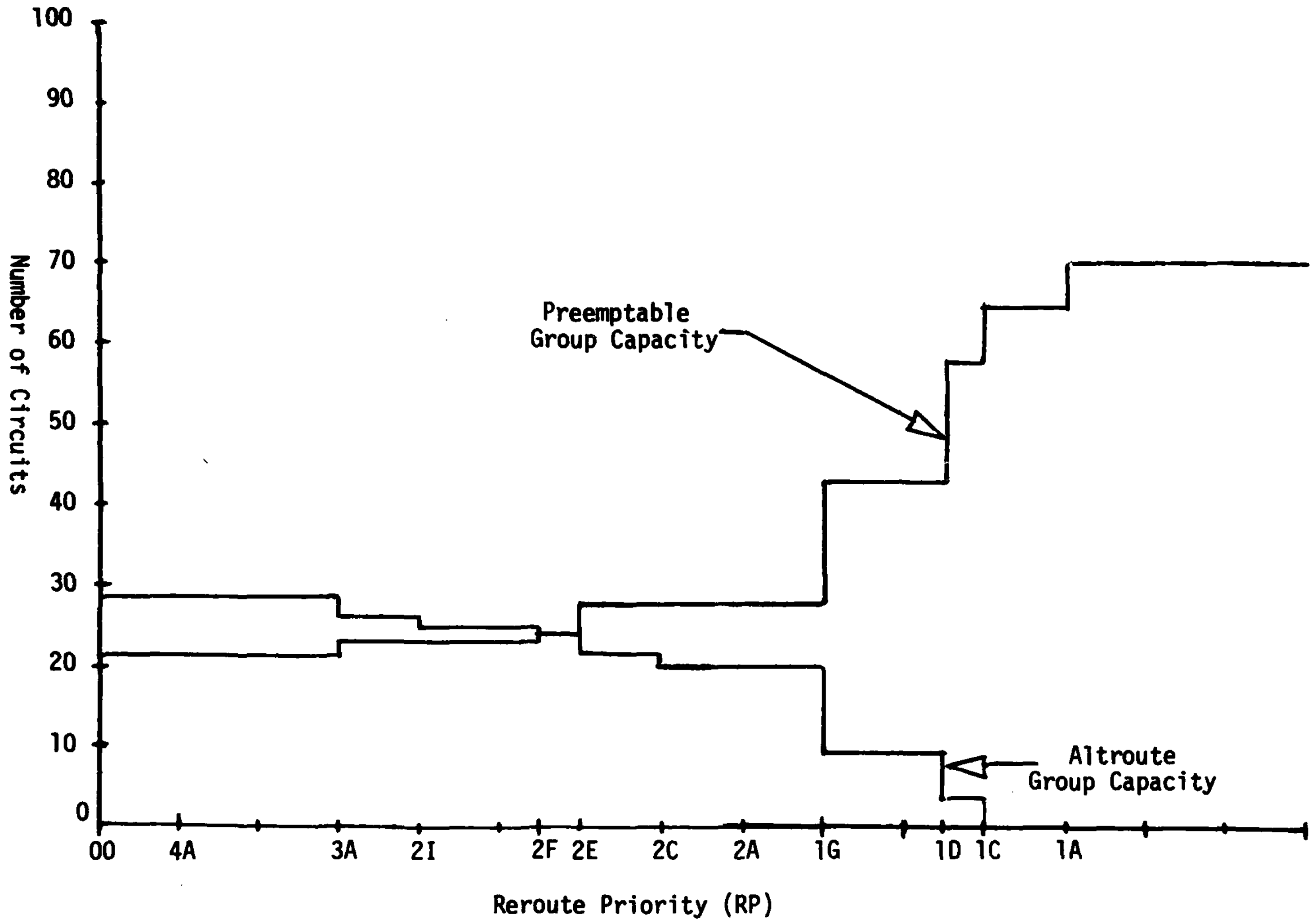

Figure A-3. Graphic View of Preemption Selections for Step 1a

The curve labelled "Preemptable Group Capacity" is the number of circuits on the six trunks that lie below the listed RP level. The "Altroute Group Capacity" curve shows the number of circuits in the altroute group that are above the listed RP. The intersection of the curves gives the RP level for the lowest RP circuit altrouted over the six trunks. The same result presented in Table A-2 is given by this plot.

The next step in creating the label for MAM (of the altroute segment from HIN) is to calculate the costs. As explained in Report 3 (Section 2.6.3), the cost of an altroute segment is taken to be the route cost for the highest RP circuit in the altroute group. In this example, we have four RP 1C circuits which tie for the highest RP circuit. The costing will in this case be the average over all four 1C circuits.

The cost of the route to MAM from HIN is found for all four RP 1C circuits. All four have reached MAM by preempting RP 00 circuits so that there is no preemption cost contribution (the cost from Figure A-2 is zero). The highest RP circuits are paired with the lowest RP preemptable circuits even though they could preempt higher RP circuits on the six trunks. This makes the route cost reflect the cost that would exist if each high RP circuit were altrouted by itself. The lower RP circuits in the altroute group are just being carried along in this altroute search as a bonus. They do not theoretically rate consideration until the highest RP circuits have been altrouted.

The route cost will now be found from the patching and mileage costs. The path between HIN and MAM has five links whose mileages add to 102 miles. When a patching cost for one station is added, the cost sum is 152. This is the known cost of the four 1C circuits' altroutes from HIN to MAM.

The last item required for the MAM label is an estimate of the mileage to the goal station of Langerkopf (LKF). This estimate is made by examining pairs of paths that MAM and LKF are on. We determine which path pair has the shortest path mileage plus euclidean path end distance from MAM to LKF (see Report 3, Section 2.6.4 for details of this process). This particular pair of stations is estimated to be 416 miles apart using the fact that the MAM to Feldberg (FEL) path and FEL to LKF path intersect at FEL. This cost is added to the known altroute cost to yield an estimated total altroute cost of 568. This number will be compared to other labelled OPEN stations in the TREE file in order to determine which partial altroute is most promising for further expansion.

A summary of the altroute segments over link M0095 is given below. This type of summary will be used for the remainder of the search steps. This first step was presented in detail only to clarify the process used in the altrouting algorithm.

Search station: HIN (now labelled as CLOSED). Files records read: 1 link, 7 trunks.

Accessible* Stations	Trunks Used	Highest RP Preempted	Circuits Altrouted	Known Segment Cost	Estimated Total Cost
MAM	33JMA1	00	24:	152	568
	33JMA2	00	4, 1C 5, 1D		
	33JMA3	--	11, 1G 2, 2C		
	33JMA4	3A	2, 2E		
	33JMA5	2F			
	33JM15	00			

*These stations are given search status OPEN.

Step 1b--The other link out of Hillingdon is M0054. This link allows access to the satellite link at Croughton. Unfortunately, the circuits on the satellite link are all RP 1C and thus, circuits cannot be preempted further than Croughton in this direction and allow expansion of the altroute.

Table A-3 summarizes all of the altroute segments generated from Hillingdon. The data listed in Table A-3 represents all OPEN search stations' labels at this point.

Step 2--The lowest cost OPEN station listed in the HIN CLOSED station label summary (see Table A-3) is Croughton. As mentioned earlier, no stations are accessible from Croughton due to the lack of preemptable circuits. Croughton is labelled as CLOSED but no new OPEN stations are generated.

Step 3--The only other OPEN station to examine (and thus the lowest cost OPEN station) is MAM. The only link to examine is T0110 to Hoek Van Holland. The link entering MAM is not examined because we have not jumped over the goal station in reaching MAM. The link used to enter a station will be considered only when "back-hauling" is required. There are three backbone stations accessible from MAM over this link: Muhl (MUL), Feldberg (FEL), and Donnersberg (DON). Remember only backbone stations are worth considering in an altroute; all other stations are on spurs which lead to dead ends in terms of altrouting. The label summary for these stations is given in Table A-4. Notice that this step limits the altroute group to fewer circuits than could be altrouted to MAM from HIN. These three stations compose the entire OPEN station list at this point in the search.

TABLE A-3. LABEL SUMMARY FOR STEP 1

Search station: HIN. File records read: 1 station, 2 link, 13 trunk.

Accessible Stations	Trunks Used	Highest RP Preempted	Circuits Altrouted	Known Segment Altroute Cost	Estimated Total Altroute Cost
MAM	33JMA1	00	24:	152	568
	33JMA2	00	4, 1C		
	33JMA3	--	5, 1D		
	33JMA4	3A	11, 1G		
	33JMA5	2F	2, 2C		
	33JMA6	--	2, 2E		
	33JM15	00			
CRO	33JMB1	--	19:	96	550
	33JMB2	--	4, 1C		
	33JMB3	--	5, 1D		
	33JMB4	2D	10, 1G		
	33JMB0	00			
	33JMB8	00			

TABLE A-4. LABEL SUMMARY FOR STEP 3

Search station: MAM. File records read: 1 station, 1 link, 6 trunk.

Accessible Stations	Trunks Used	Highest RP Preempted	Circuits Altrouted	Known Segment Cost	Estimated Total Altroute Cost
MUL	34JZH1	2C	9: 4, 1C 5, 1D	645	741
FEL	34JZA6 34JZB1 34JZB2 34JZB3	00 3A 00 3A	24: 4, 1C 5, 1D 11, 1G 2, 2C 2, 2E	548	618
DON	34CZB1	00	9: 4, 1C 5, 1D	650	682

Step 4--Feldberg is selected as the lowest cost OPEN station. The number of links with which it can generate altroutes is six (exclude the M0291 link because it was used to enter FEL). The stations accessible from Feldberg are:

Langerkopf (LKF)	M0063
Bann (BAN)	M0063-M0331
Donnersberg (DON)	M0298-M0372
Frankfurt (FKT)	M0070
Schoenfeld (SCH)	M0891-M0890
Hiedelberg (HDG)	M0298-M0372-M0305
Lindsey (LSY)	D0123

Table A-5 summarizes the labelling of these stations from Feldberg. Notice that the goal station (Langerkopf) is labelled in this step. The search does not terminate, however, until Langerkopf is selected as the lowest cost OPEN station. Donnersberg is reached again by this step, but the cost of the route from Feldberg is higher than the cost from Martlesham Heath due to an additional patch at Feldberg. The label for Donnersberg from MAM is kept. The label from FEL is ignored.

Step 5--The group of OPEN stations are all stations in Table A-4 and Muhl and Donnersberg in Table A-3. The lowest cost station is Langerkopf at 598. Since it is the goal of the search, the search will end here. The altroute is then defined by the parent station back-pointers:

Hillingdon--Martlesham Heath	M0095-M0096-M0365-M0098
Martlesham Heath--Feldberg	T0110-T0111-D0112-M0291
Feldberg--Langerkopf	M0063

Circuits altrouted: Four--1C/5, 1D/11, 1G/1, 2C

A.3 EXAMPLE 2

The link from Feldberg to Langerkopf fails (M0063). This altrouting scenario is the one used in Report 3 (Section 2.8) to examine response times in altrouting. It will be used here as an example of trunk altrouting. The trunks out of service due to the link failure are:

44JMQ1	Langerkopf--Feldberg
44JMQ2	Langerkopf--Feldberg

TABLE A-5. LABEL SUMMARY FOR STEP 4

Search station: FEL. File records read: 1 station, 6 link, 35 trunk.

Accessible Stations	Trunks Used	Highest RP Preempted	Circuits Altrouted	Known Segment Altroute Cost	Estimated Total Altroute Cost
LKF	44JMQ1	2E	21:	598	598
	44JMQ2	--	4, 1C		
	44JMQ3	--	5, 1D		
	44JMQ4	--	11, 1G		
	44JMQ5	2E	1, 2C		
	44JMQ6	--			
	44JMQ7	2E			
BAN	44JMX7	2C	10:	680	692
			4, 1C		
			5, 1D		
			1, 1G		
DON	44XMD1	2E	18:	652	684+
	44CMD2	--	4, 1C		
	44CMD3	3A	5, 1D		
	44CMD4	00	9, 1G		
	44CMD5	--			
	44CMD6	3A			
	44CMD8	--			

*Goal station LKF has been labelled.

+This label cost higher than previous label in Table A-3. Ignore this DON label.

TABLE A-5. LABEL SUMMARY FOR STEP 4 (concluded)

Search station: FEL. File records read: 1 station, 6 link, 35 trunk.

Accessible Stations	Trunks Used	Highest RP Preempted	Circuits Altrouted	Known Segment Altroute Cost	Estimated Total Altroute Cost
FKT	44CMN1	00	24:	609	690
	44CMN2	--	4, 1C		
	44CMN3	--	5, 1D		
	44CMN4	00	11, 1G		
	44CMN5	00	2, 2C		
	44CMN6	--	2, 2E		
	44CMN7	--			
	44CMN8	--			
SCH	44JMX1	--	9:	695	791
	44JMX2	--	4, 1C		
	44JMX3	00	5, 1D		
	44JMX4	--			
HDG	44CMH1	2C	9:	688	756
			4, 1C		
			5, 1D		
LSY	44JMP1	00	24:	614	676
	44JMP2	--	4, 1C		
	44JMP4	00	5, 1D		
	44JMP5	00	11, 1G		
	44JMP6	--	2, 2C		
	44JMP8	--	2, 2E		
	44JMP9	--			

44JMQ3	Langerkopf--Feldberg
44JMQ4	Langerkopf--Feldberg
44JMQ5	Langerkopf--Feldberg
44JMQ6	Langerkopf--Feldberg
44JMQ7	Langerkopf--Feldberg
44JMX7	Bann--Feldberg
34CZB1	Donnersberg--Martlesham Heath
34JZF1	Langerkopf--Martlesham Heath

The entry point is again the trunk level altrouting routine. This time, however, we will find a trunk altroute. The trunks are selected by importance for altrouting in the order of the sum of their circuits' RPs. This ensures that the largest number of important circuits are handled rapidly. *In this group of trunks, 44JMQ5 is the most important trunk. Its highest* carried RP is 1A, and its lowest RP circuit is 00. Since it has a 00 RP circuit, the altroute of this trunk can only use spare groups. It can never preempt an entire trunk due to the circuit preemption rule acting on the RP 00 circuits.

<u>Altrouting Trunk 44JMQ5</u>

<u>Step 1</u>--The search for an altroute for this trunk begins at Langerkopf (LKF) and seeks a goal station of Feldberg (FEL). The altroute path "costs" will be calculated as the circuit costs were in Example 1. The only difference is in the preemption cost which is now taken as the sum of all of the preempted trunk's RPs. This cost will be much larger in the sum cost due to 12 circuits' RPs being added into the sum. For this reason, the scale factor of this component of total cost will be reduced by 12. This renews

the cost component equivalencies derived in Example 1. In effect, we are setting an average preempted circuit RP of 2A on a preempted trunk equivalent to two patches or 100 miles of route mileage.

The links from Langerkopf over which the altroute search is made are:

Link	Langerkopf to:
M0331	Bann
M0378	Pirmasens
M0068	Muhl
M0671	Donnersberg
M0373	Friolzheim

The link to Feldberg is not considered because it is the failed link. The only link over which this altroute cannot access a new station is M0671; there are no spare groups. The stations accessible over the remaining links at the group or circuit level are labelled and listed in Table A-6.

Step 2--The station at Donnersberg is the lowest cost OPEN station at this step and will be examined for altroute expansion next. The links out of Donnersberg are:

Link	Donnersberg to:
M0364	Lindsey
M0372	Rhein Main
M0305	Heidelberg
M0724	Pirmasens

TABLE A-6. LABEL SUMMARY FOR STEP 1

Search station: Langerkopf. File records read: 1 station, 6 link.

Accessible Stations	Link and Group or Trunk Used	Highest RP Preempted	Known Segment Cost	Estimated Total Altroute Cost
Bann	M0331 2/5*	Spare	62	144
Schoenfeld	M0068 2/4	Spare	146	234
Donnersberg	M0378 3/2	Spare	93	139
Stuttgart	M0373 4/1	Spare	123	220

*Supergroup/group used.

T0328	Hohenstadt
M0671	Langerkopf
M0308	Koenigstuhl

The link to Langerkopf is ignored because any labelling of it will exceed the current labelled cost: zero (it is the starting station). The link to Pirmasens is the link used to enter Donnersberg and need not be examined for a "back-haul" because the goal station has not been jumped over in the path to Donnersberg. The labelled stations over the remaining links are given in Table A-7.

Step 3--The OPEN stations at this step are: Schoenfeld, Stuttgart, Feldberg, Koenigstuhl and Lindsey. Lindsey is the lowest estimated path cost of any. It will be labelled CLOSED and examined next. The only station accessible

TABLE A-7. LABEL SUMMARY FOR STEP 2

Search station: Donnersberg. File records read: 1 station, 6 link.

Accessible Stations	Link and Group or Trunk Used	Highest RP Preempted	Known Segment Cost	Estimated Total Altroute Cost
Feldberg	M0372 5/3	Spare	197	197
Koenigstuhl	M0308 3/5	Spare	183	240
Lindsey	M0364 1/1	Spare	173	189

over its only link is Feldberg (D0123, 2/5). The cost of the label to Feldberg from Lindsey is 239. This cost exceeds the previously established label from Donnersberg so it is not considered further.

Step 4--The lowest cost OPEN station is now Feldberg, the goal station. The search ends at this step with the altroute established:

Langerkopf--Donnersberg	M0378	3/2
Donnersberg--Feldberg	M0372	5/3
	M0298	

Cost = 197

A.4 ALGORITHM EXECUTION TIME

The final analysis of this section will be to estimate the computer execution time required in order to do the two examples presented here. Estimation of this time will be made using the software sizing estimates for functional program sections (See section 4.4.1.2 of this report). The time for the computer execution will include the time required to complete the HOL instructions specified in the software sizing plus the time required to access the disc during record retrieval. Typical time for disc access will be taken as 50 milliseconds. The HOL instructions will be assumed to be composed of an average of five assembly level instructions. The average assembly level execution time for a variety of computers the size of the ACOC machine is about five microseconds. This makes the HOL execution time approximately 25 microseconds.

The estimation of the disc accesses, HOL instructions, and computer execution times needed for each step in the two examples are given in Tables A-8 and A-9. These results show a rather small execution time for each example in comparison with other activities occuring during altroute implementation (see Report 3, *Section* 2.8). This result for these two typical altrouting examples demonstrates the feasibility of real-time altroute search algorithms as a part of altroute control.

TABLE A-8. EXECUTION TIME FOR EXAMPLE 1

Step	Number of Disc Reads*	Number of HOLs	Execution Time (Secs)
Job queue set-up	22	5420	1.24
Step 1a	8	1580	0.44
Step 1b	7	1370	0.38
Step 2	3	310	0.16
Step 3	8	2755	0.47
Step 4	42	8660	2.32
Step 5	--	15	0.00
Put altroute and preemptions into data base	84	4100	4.30
Totals	174	24,210	9.31

*Does not include possible fault files needed to identify failed segments.

TABLE A-9. EXECUTION TIME FOR EXAMPLE 2

Step	Number of Disc Reads	Number of HOLs	Execution Time (Secs)
Job queue set-up	11	2400	0.61
Step 1	7	2225	0.41
Step 2	7	1755	0.39
Step 3	2	690	0.12
Step 4	--	15	0.00
Put altroute and preemptions into data base	3	145	0.15
Totals	30	7230	1.68

APPENDIX B

MANNING BENEFITS ANALYSIS FOR ALTROUTE CONTROL

B.1 INTRODUCTION

Due to the automation of altroute generation and implementation proposed in this study, the manpower allocated at DCS stations will be impacted. The coordination required to synthesize an altroute among a number of stations will be eliminated due to the ACOC altroute synthesis algorithms. The patching instructions will be automatically generated and transmitted to stations involved. The future deployment of CRUs will further reduce manpower by allowing remote, automatic patching implementation of the altrouting controls. Finally, the integration of the altrouting algorithms with the ACOC data base manager will provide updated route changes without reporting via the station personnel. The manpower reductions at the station level due to altroute control will thus be in coordination, patching and reporting functional areas.

B.2 AN ANALYSIS METHOD

The analysis of the impact of altrouting control upon manpower at the station level will be analyzed with a queueing model of controller functions in the face of non-scheduled outage-related tasks. The model used was developed in Reference 9. The purpose of that report was to formally define the manpower impact analysis tools to be used in automation studies such as this one. The model is appropriate for this study with only a few modifications.

The analysis model describes the station controller's activities as a simple first-in, first-out queue. Each controller is defined as a server to the queue inputs which are divided into three activities related to outages:

- Circuit restoration and fault clearing
- Assistance to other stations
- Near-real-time reporting

The queue of tasks in these areas is set up to be infinite in capacity with each task assigned to the next available controller, regardless of the nature of the task. The task arrival time and task processing time are assumed to have constant conditional probability density. The queue is characterized by the sum of the arrival times and an average process time which reflects the individual times for the three tasks described above.

The steady-state output of the queue and in-process task load is used as the service measure of personnel at a station. The circuit restoration tasks in the queue or in-process are assumed to represent out-of-service circuits. A station availability, defined as the percent of circuits at a station that are in service, is the measure of effectiveness of the manning level at the station. Changes in arrival and process time due to altroute control will be made in an effort to determine how many fewer controllers can be used to achieve the same availability measure. In addition, the idle time from these randomly arriving outage tasks will be monitored so that estimated manpower reductions are consistent with the idle time necessary for scheduled tasks.

The queueing model is defined by the following definitions and equations:

Probability that an event will occur in time dt at time t assuming that it has not occurred prior to t = a constant (the "rate constant" of the process)

λ_1 : Rate constant for circuit outage arrivals at the station

μ_1 : Rate constant for handling circuit outages

λ_2 : Rate constant for the arrival of inter-station assistance requests

μ_2 : Rate constant for satisfying inter-station assistance requests

λ_3 : Rate constant for required near-real-time reporting

μ_3 : Rate constant for handling a near-real-time report

u : Average task processing rate constant

λ : Total task arrival rate constant

k : Number of controllers at a station

q : Average steady-stage task load in the queue and in-process

$$q = B \frac{\rho}{1-\rho} + K\rho$$

$$\rho = \frac{\lambda}{\mu k} \qquad \lambda = \lambda_1 + \lambda_2 + \lambda_3$$

$$\mu = \frac{\lambda}{\frac{\lambda_1}{\mu_1} + \frac{\lambda_2}{\mu_2} + \frac{\lambda_3}{\mu_3}}$$

$$B = \frac{1 - \frac{a}{b}}{1 - \rho\frac{a}{b}}$$

$$a = \sum_{i=0}^{k-1} \frac{(K\rho)^i}{i!}$$

$$b = \sum_{i=0}^{k} \frac{(K\rho)^i}{i!}$$

A = Station measure of service availability

$$A = \frac{(\text{No. of crkts. handled by a station}) - q \frac{\lambda_1}{\lambda}}{(\text{No. of crkts. handled by a station})}$$

Station percent idle time = $t_k = (1 - \rho) \times 100\%$.

B.3 THE BASELINE MANNING ANALYSIS

The first step in examining benefits of altrouting controls is to establish the baseline manning availability measure and idle time percentages for the DCS stations. The difference between this baseline analysis and the results of latter analyses with controls considered will serve to estimate the possible manpower reductions and benefits of altrouting controls.

The source of the rate parameters for the baseline analysis comes from the Croughton manpower survey (Reference 10), the "O&M Manning Studies" (Reference 9), and the "Digital Network Control Cost Benefits Study" (Reference 11). The Croughton manning was analyzed and reported in 1974. The task arrival and task process times of that study were analyzed in the two reports to arrive at the rate constants defined earlier.

Rate Constant	Estimate Value for Croughton
λ_1	1.10/hour
μ_1	0.43/hour
λ_2	13.44/hour
μ_2	5.46/hour
λ_3	2.60/hour
μ_3	13.70/hour

Several modifications of this basic data must be made before using it as the baseline of this analysis. First, ATEC is assumed to be fully deployed in the baseline model of this study. Reference 11 estimates the following average changes in the pre-ATEC Croughton rate constants due to ATEC deployment:

Rate Constant	Estimate Post-ATEC Value for Croughton	
λ_1	0.99/hour	(-10%)
μ_1	0.47/hour	(+10%)
λ_2	13.44/hour	no change
μ_2	7.64/hour	(+40%)
λ_3	2.6/hour	no change
μ_3	21.9/hour	(+60%)

The reductions in the task rates will be briefly explained here. The reduction in processing time for the circuit outages is primarily a result of ATEC fault isolation algorithms. The circuit outage arrival reduction is attributed to the ATEC performance reporting function which would pick up radio degradations before they could become serious enough to impact service.

The impact of ATEC upon inter-station assistance times would be to automate testing which accounts for 40% of the activity for which stations require interaction. Finally, the reduction in reporting times is an estimate first made in the "O&M Manning Studies" report and is justified by the fact that ATEC will provide automatic report transmission and report format prompting in report preparation.

This analysis will diverge from the previous work in the estimate of the circuit outage restoration rate parameter. The sources of this parameter point out that this rather long time per circuit outage is not due to the volume of work the controller must do but to the long time between commencement of action and final resolution. In fact, the time spent per circuit outage at the Croughton station was estimated at 8.5 minutes for a circuit not requiring altrouting and 20 minutes for a circuit requiring altrouting action at the station. The extra time per outage in this queueing model assumes that the controller is idle for two hours. This assumption is certainly not true; the controller is no doubt working on other tasks during this time between outage-related activities. To model this situation more clearly, either the controller should be considered a multi-server or the actual task process time should be used for the rate constant in this queueing model. The latter approach is selected here. The circuit outage rate constant for Croughton will be set at 5.3/hour to reflect the fact that 25% of the circuits will require the 20-minute altrouting process time, and the other 75% will use only 8.5 minutes of the controller's time. The adjustment of this pre-ATEC data for the baseline model of this analysis will reduce the response time for fault isolation to one minute due to ATEC fault isolation automation. The post-ATEC circuit outage rate constant for this baseline analysis is then 8.9/hour.

The next adjustment of the Croughton rate constants is to scale them for the size of each station's circuit load. The arrival rates of each message type will be scaled from the Croughton data using the relative number of circuits at a station compared to Croughton. This should adequately represent the task load variations. The process times will be left unchanged under the assumption that the quality of controllers at all sites is uniform. Table B-1 summarizes the scaling of task arrival times for the stations in the European DCS of this study. The manpower assigned to each station is also given and represents the personnel specified as technical controllers (Reference 11).

The result of this baseline analysis is presented in Table B-2. This table presents the service availability measure and idle time for the baseline manning levels. This data will be used later in comparison with the altroute control manning in order to determine benefits from those controls.

B.3 MANNING BENEFITS DUE TO CENTRALIZED ALTROUTE CONTROL

The main automation providing a manpower impact upon the stations is the centralization of altroute synthesis at ACOC rather than its current decentralized station level operation. The effect of this control is to reduce the circuit outage task process times at the stations. The controllers now receive their altroute patching messages from ACOC. The altroute is completely defined. No inter-station coordination is required to find an altroute. The station controller will review the plan as it refers to his site and indicate to ACOC whether it seems possible. The concurrence of all involved stations then permits controller patching of the altroute per the ACOC route. No reporting of the route upward is needed.

TABLE B-1. SCALED TASK ARRIVAL RATE CONSTANTS

Station	Number of Controllers	Scale Factor	Arrival Rates λ_1	λ_2	λ_3
Bann	12	1.4	1.56	18.8	3.6
Berlin	9	.63	.69	9.3	1.8
Croughton	12	1.0	1.1	13.4	2.6
Donnersberg	10	4.3	4.7	57.6	11.2
Feldberg	16	4.2	4.6	56.5	10.9
Heidelberg	10	.58	.64	7.8	1.5
Hillingdon	20	2.4	2.6	32.3	6.2
Kaiserlautern	10	.74	.8	10.0	1.9
Koenigstuhl	5	2.4	2.6	32.3	6.2
Landstuhl	7	.26	.29	3.5	.68
Langerkopf	26	3.1	3.4	41.7	8.1
Martlesham Heath	18	1.7	1.9	22.9	4.4
Mildenhall	4	.63	.69	9.3	1.8
Muhl	7	1.3	1.4	17.5	3.4
Pirmasens	20	1.4	1.4	17.5	3.4
Ramstein	17	1.1	1.2	14.8	2.9
Rhein Mein	6	.32	.35	4.3	.83
Schoenfeld	6	1.5	1.7	20.0	3.9
Sembach	16	.53	.58	7.1	1.4
Stuttgart	4	1.7	1.9	22.8	4.4
Total	235				

TABLE B-2. BASELINE MANNING ANALYSIS SUMMARY

Station	Baseline Manning	Station Availability	Percent Idle Time
Bann	12	.999493	77.
Berlin	9	.999493	86.
Croughton	12	.999493	83.
Donnersberg	10	.999307	15.
Feldberg	16	.999461	48.
Heidelberg	10	.999493	88.
Hillingdon	20	.999453	76.
Kaiserlautern	10	.999493	85.
Koenigstuhl	5	.997617	5.
Landstuhl	7	.999493	93.
Langerkopf	26	.999313	76.
Martlesham Heath	18	.999493	81.
Mildenhall	4	.999485	69.
Muhl	7	.999491	63.
Pirmasens	20	.999493	86.
Ramstein	17	.999493	87.
Rhein Main	6	.999493	89.
Schoenfeld	6	.999477	50.
Sembach	16	.999493	93.
Stuttgart	4	.998496	16.
Total	235		

The major reflection of this task reduction in the rate of circuit outage processing is to eliminate the coordination time from the Croughton response time (4.5 minutes for circuits requiring altrouting). The reporting time of 4.12 minutes for each altroute is reduced to 1 minute per the analysis in Report 3 (Section 2.8). This increases the Croughton rate constant for circuit outage processing to 12.4/hour (+39%). The percentage increase in this rate constant is applied to all of the individual stations in calculating the new manning due to altroute control.

The results of the manpower analysis for the case of altroute control is given in Table B-3. The queueing analysis was run at each station for all levels of manning up to the baseline level. The new manpower was arrived at by selecting a manning level yielding the same or better station availability with no more than a 5% reduction in idle time. The manpower savings per station are tabulated and summed over the entire European area. The estimated cost savings due to this reduction in manning is estimated at $0.802 million per year (using $20,563 per man year as a cost of manning, Reference 11).

TABLE B-3. MANPOWER ANALYSIS WITH ALTROUTE CONTROLS

Station	Manning With Altroute Control	Manning Reduction	Station Availability	Percent Idle Time
Bann	10	2	.999501	73
Berlin	7	2	.999501	82
Croughton	10	2	.999501	80
Donnersberg	10	0	.999345	16
Feldberg	16	0	.999470	49
Heidelberg	8	2	.999501	86
Hillingdon	17	3	.999579	72
Kaiserlautern	8	2	.999541	82
Koenigstuhl	5	0	.998154	6
Landstuhl	5	2	.999501	90
Langerkopf	22	4	.999471	72
Martlesham Heath	15	3	.999501	78
Mildenhall	4	0	.999494	69
Muhl	7	0	.999499	64
Pirmasens	15	5	.999501	82
Ramstein	13	4	.999501	83
Rhein Main	5	1	.999501	88
Schoenfeld	6	0	.999486	51
Sembach	9	7	.999501	89
Stuttgart	4	0	.999024	17
Totals	235	39		

APPENDIX C

AUTOMATIC ALTROUTE AND RESTORAL ALGORITHM SIZING BACKUP

The following tables provide the detailed software sizing for the altroute and normalization routines as presented in the flow charts in Report 3. These routines were combined into software modules consistent with the sizing effort that was performed and presented in Report 2. These tables back up the sizing presented in Section 4.4.

MAIN CALLING ROUTINE--TRUNK SECTION

Processing Module	HOL Instructions
Update trunk altroute catalog	20
Select trunk at top of altroute catalog	10
Select new FS	10
Notify users of trunk to be pumped	50
Catalog preempted trunks by RP, etc.	10
Direct stations to PATCH altroute	50
Create TF for altroute and appropriate cross-references	30
Delete T from catalog of trunks to altroute	5
Failure exit-enter circuits in ckt altroute catalog	10
Identify circuits that fail goal station definition search	10
Deletes T from normalization catalog	5
Compare old and new altroute	15
Delete segments of old altroute	10
Create list of stations bounding failure	20
Flag failed altroute	5
Label FS as a failed station; get new FS	10
Place ckts on normalization catalog	5
Transfer preemptions	10
Decision logic	25
Calling logic	10
	320

MAIN CALLING ROUTINE--CIRCUIT SECTION

Processing Module	HOL Instructions
Remove cx from ckt normalization catalog	10
Update cx entry in altroute catalog	20
Select top ckt in altroute catalog	5
Sort and collect ckts with same FS and ITS	15
Catalog ckts in ALTR with complete altroute and select a ckt	20
Notify users of preempted ckts	50
Catalog ckts that are preempted in normalization catalog and altroute catalog	20
Direct stations to PATCH altroutes	50
Create CFs for altroute ckts and appropriate xrefs	20
Drop altrouted ckts from ckt altroute catalog	5
Update TREE after altrouting or DUMP	10
Create list of stations bounding failure	20
Set flags for altroute in place but failed	10
Compare old and new altroute for commonality for subsequent action	15
Redefine FS	10
Delete cx from altroute catalog	5
Sub-vf ckt breakout/catalog/etc.	20
Decision logic	25
Calling logic	10
Update ALTR	15
Delete Common segments	10
Failure exit	10
	385

TRUNK ALTROUTING ROUTINE

Processing Module	HOL Instructions
Altroute analysis	70
Update list of stations	15
Purge temporary files	10
Enter station data in TREE file	15
Search CNF to find paths	20
Failure Exit	10
Find lowest cost HITS and HTS	10
Sort links to x/catalog	15
Catalog trunks; flag spare trunks; order trunks	10
Test trunk tx for certain conditions	5
Delete tx from trunk catalog	10
Open TREE entry set flags	15
Test trunk catalog empty	5
Expand altroute	20
Satellite link logic	35
Cost analysis	25
Decision logic	25
Calling logic	10
Success exit	15
	340

CIRCUIT ALTROUTING ROUTINE

Processing Module	HOL Instructions
Check preplanned altroutes	40
Enter data into TREE file	15
Search CNF	20
Catalog links/trunks	15
Test tx	10
Add to list	15
Locate circuits	40
Test failures for various alterations	40
Delete files/entrys from catalogs	15
Decision logic	25
Calling logic	15
Failure exit	10
Success exit	15
Goal station defer	10
Expand altroute	50
Satellite altroute logic	60
Cost analysis	30
	445

COST CALCULATING ROUTINE

Processing Module	HOL Instructions
Test x and ps on path	20
Add patching cost	10
Add RP for all preempted ckts	15
Multiply by scale factor	20
Sum link mileage	10
Sum transmission costs	10
Add cost from x's PS to the cost of x	5
Catalog ID of the paths	15
Test catalog for paths	10
Compute euclidean distance	10
Multiply x transmission cost/mile	10
Exit logic	10
Decision logic	20
Modify TREE file	20
Purge named file	10
	195

HEURISTIC COST CALCULATION ROUTINE

Processing Module	HOL Instructions
Use SCF to find distance between x and A	30
Use CNF and euclidean distance to find shortest x to a path	50
Scale mileage and store as HA in TREE	40
Find link transmission costs; add to HA	40
Decision logic	15
Multiply by mileage scale	10
Sum mileage	10
Exit logic (with Heuristic cost)	10
	205

GOAL STATION DEFINITION ROUTINE

Processing Module	HOL Instructions
Order the trunks	20
Order the end stations	20
Label OS and TS	15
Find station FS	15
Find station ITS	15
Test # of stations	10
Test # of links	10
List stations and exit	20
Test OS - one link?	15
Redefine FS	20
Failure exit	10
Decision logic	15
Success exit (with goal stations)	15
	200

CIRCUIT MATCHING ROUTINE

Processing Module	HOL Instructions
Sort circuits by port type and RP	40
Select first ckt	10
Search for match precompatible ckts	25
Do for all PT	10
Delete circuit from list	15
Decision logic	15
Match the K circuit	25
Set flag for desired circuits	15
	155

NORMALIZATION ROUTINE

Processing Module	HOL Instructions
Enter t into trunk normalization catalog	15
Delete t from trunk altroute catalog	10
Tell end stations t is in service	50
Remove preempts t made; determine normalizing patches needed	60
Send patching message for removal of altroute	50
Update LF to reflect normalization	15
Check trunk normalization catalog	5
Update flags in normalization catalog	10
Make entries in circuit normalization catalog	15
Check preempts/altroutes on c	30
Delete c from altroute catalog	10
Inform end stations that c is in service	50
Remove preempts c made; determine normalization patches	60
Send patching messages for removal of altroute	50
Update data base to reflect normalization	25
Check circuit normalization catalog	5
Update flags	10
Select new ckts	15
Decision logic	15
Exit logic	10
	510

COMMON FILE HANDLING LOGIC

Processing Module	HOL Instructions
Read trunk file (TF)	20
Read fault file (FF)	20
Read altroute TF	20
Read circuit file (CF)	20
Read TREE	20
Read ALTR	20
Delete (named) file	25
Read altroute CF	20
Read connectivity file (CNF)	20
Read station file (SF)	20
Read link file (LF)	20
Read station coordination file	20
	245